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**Kazmirski et al.**

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(54) **HIGH VELOCITY COMPRESSION DAMPING VALVE**

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(51) **Int. Cl.**
***F16F 9/508*** (2006.01)
***F16F 9/512*** (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC . ***F16F 9/512*** (2013.01); ***F16F 9/34*** (2013.01); *F16F 9/061* (2013.01); *F16F 9/065* (2013.01); *F16F 9/185* (2013.01)

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CPC ..... F16F 9/20; F16F 9/34; F16F 9/062; F16F 9/512; F16F 9/516; F16F 9/348; F16F 9/3484; F16F 9/3485; F16F 9/5126; F16F 9/5123; B60G 17/08; B62D 7/22
USPC ..... 188/280, 322.13, 322.14, 322.15, 188/282.5, 315, 317
See application file for complete search history.

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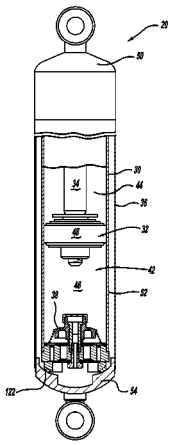
(57) **ABSTRACT**

A shock absorber includes a pressure sensitive valve assembly that controls fluid flow through the pressure sensitive valve assembly based upon the velocity of the piston assembly in the shock absorber. The pressure sensitive valve assembly restricts fluid flow as the velocity of the piston in a compression stroke increases to increase the damping loads provided by the shock absorber. A secondary valve assembly controls fluid flow through the pressure sensitive valve assembly when the pressure sensitive valve assembly is in a closed position.

**20 Claims, 13 Drawing Sheets**



(51) **Int. Cl.**

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| ***F16F 9/34*** | (2006.01) |
| *F16F 9/06* | (2006.01) |
| *F16F 9/18* | (2006.01) |

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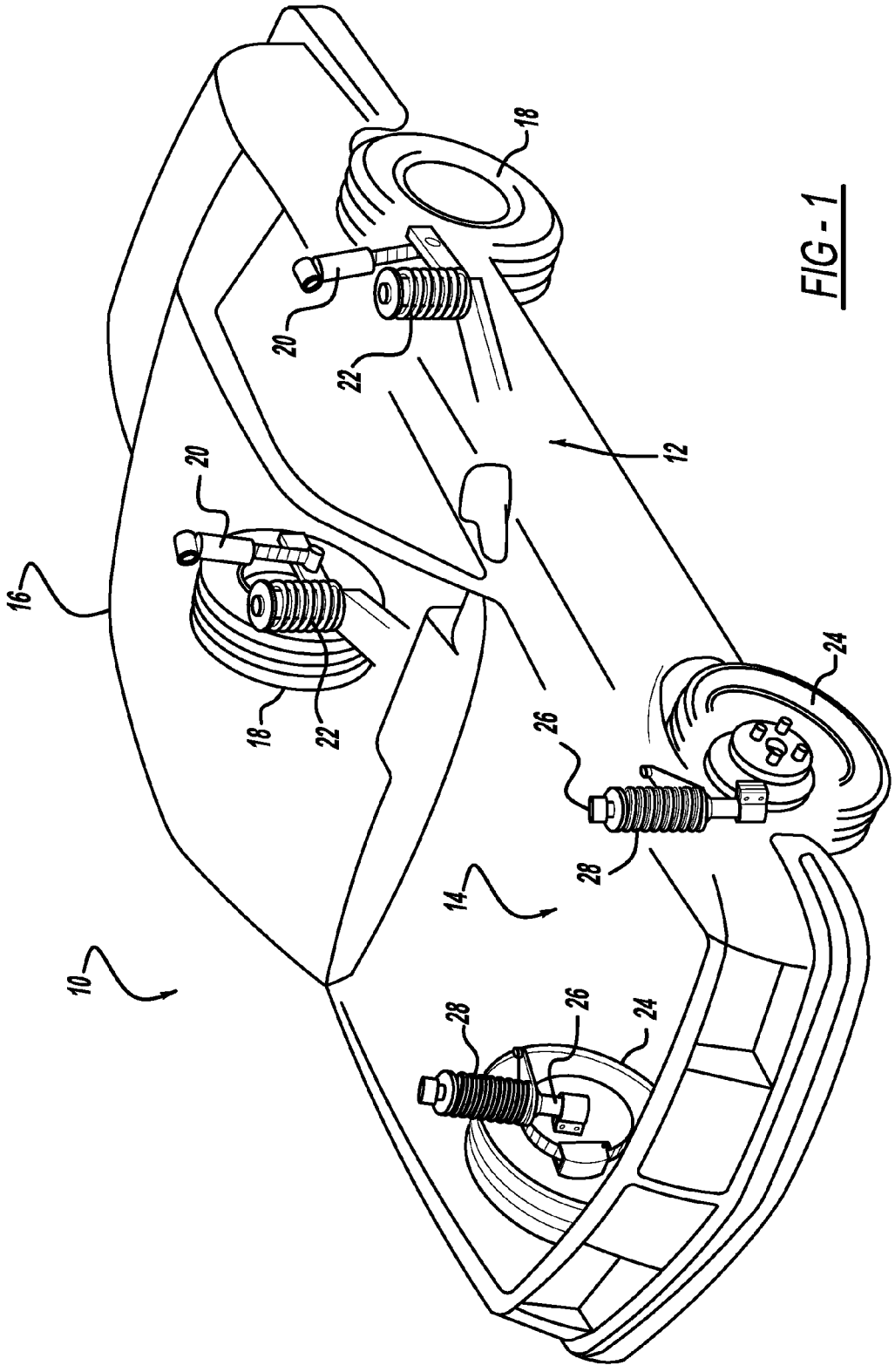


FIG - 1

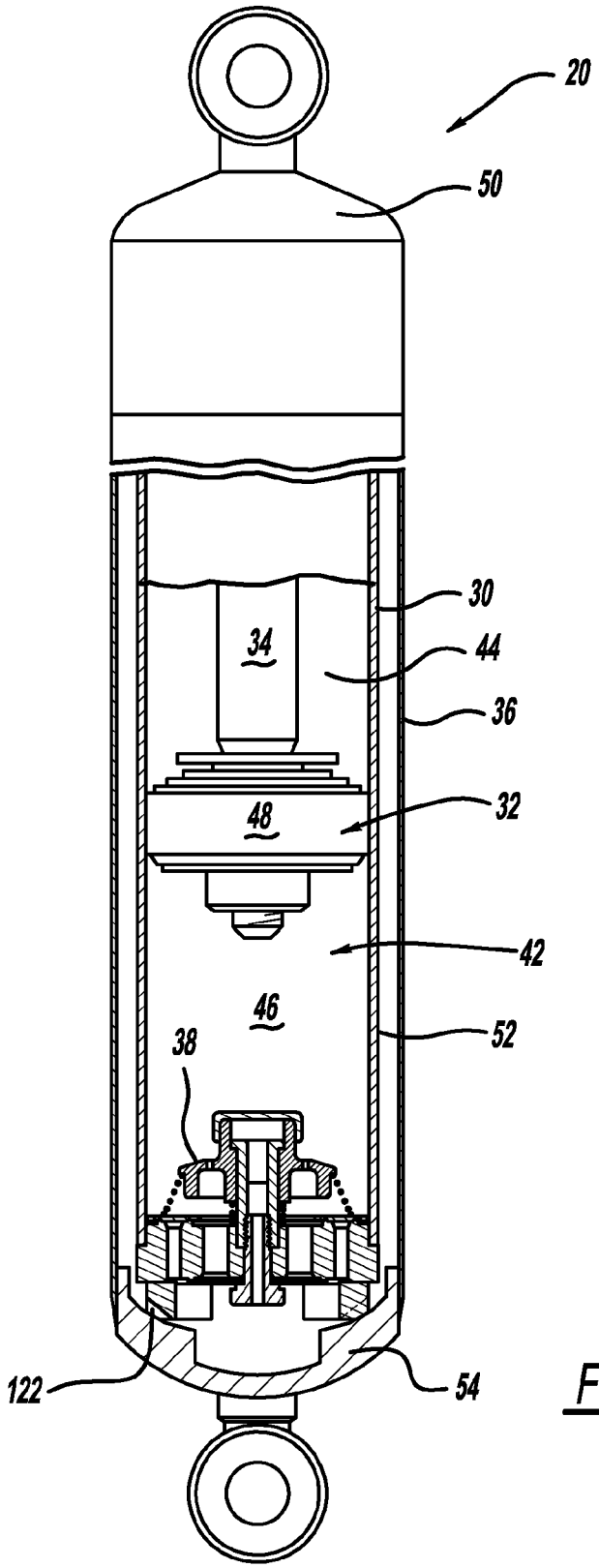


FIG - 2

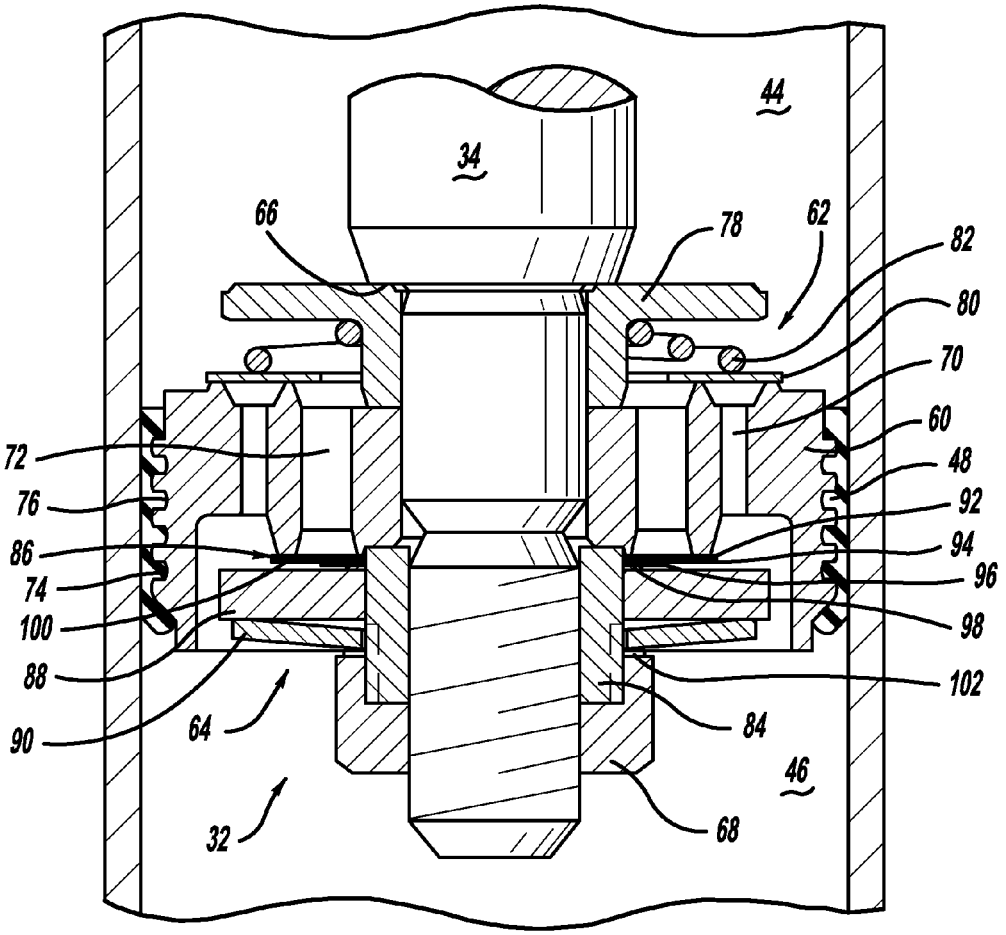
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FIG - 3

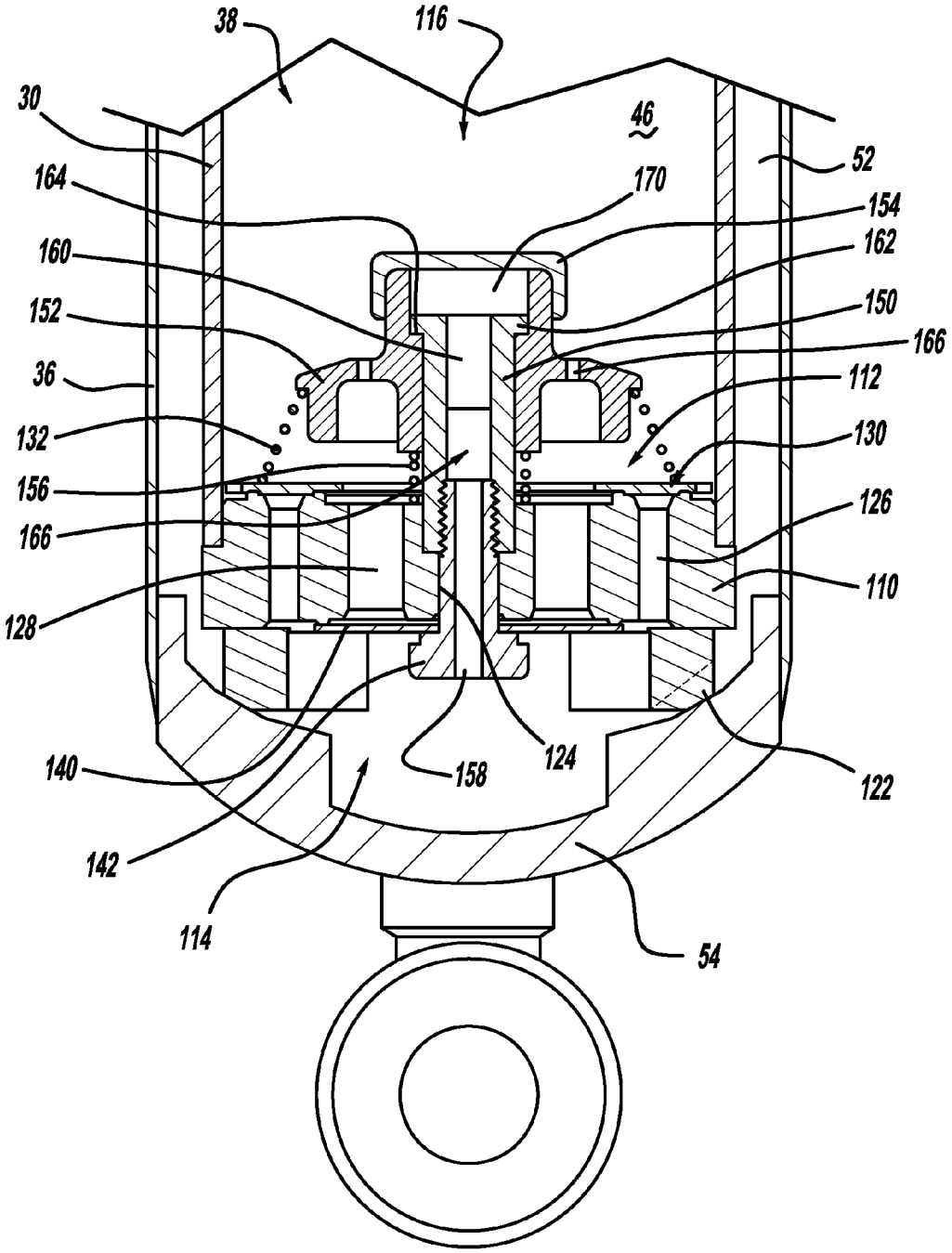
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FIG - 4

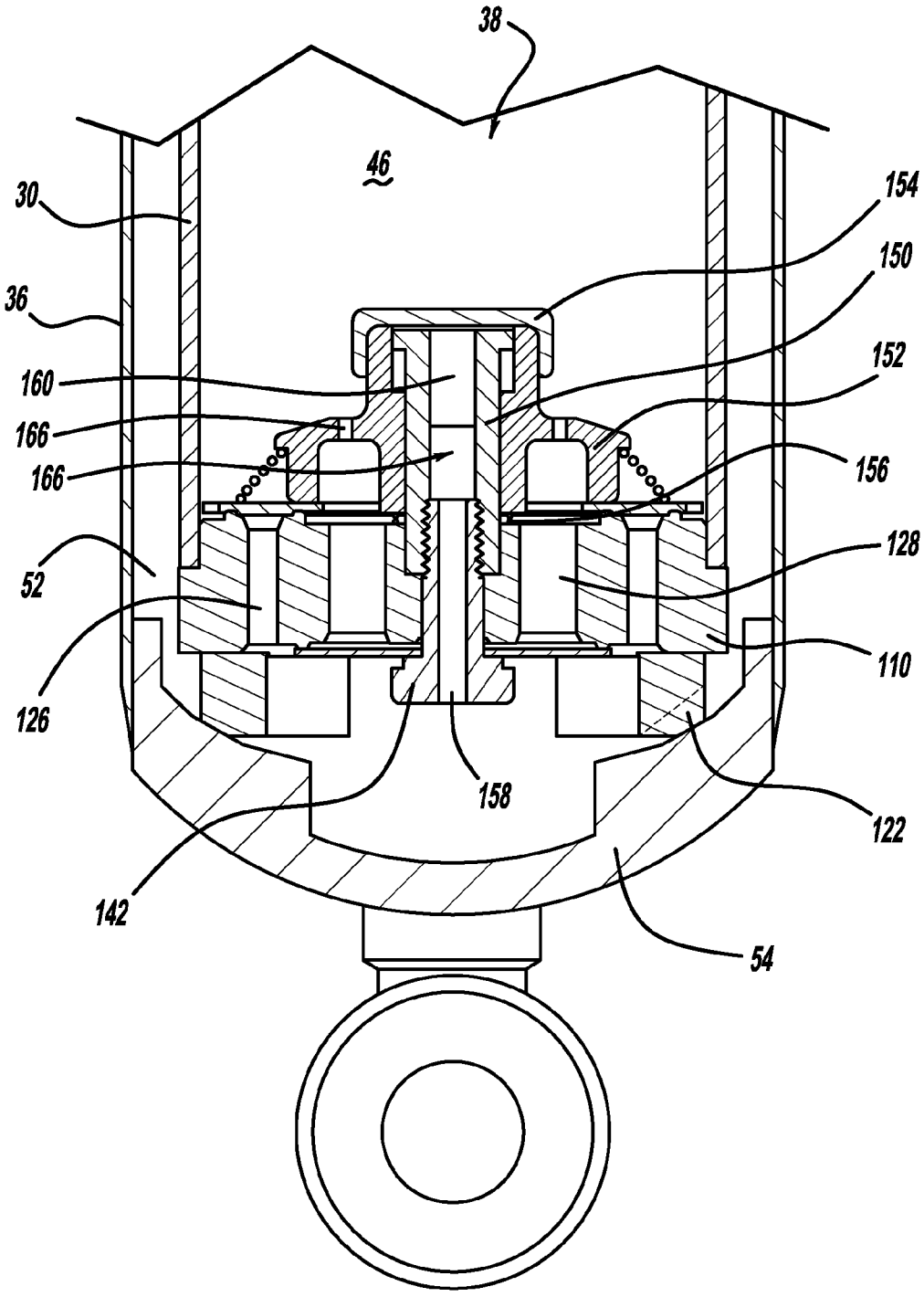
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FIG - 5

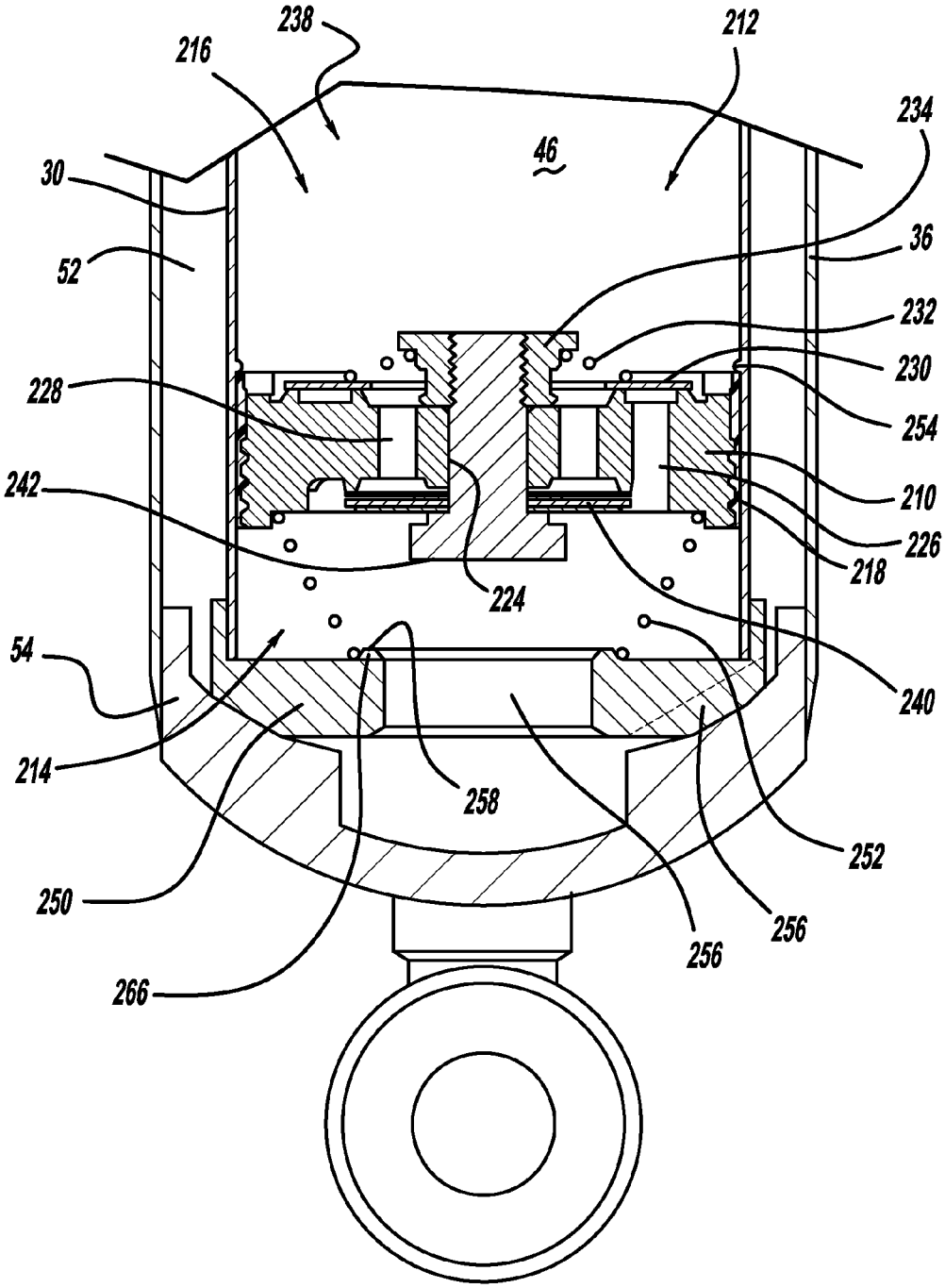
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FIG - 6

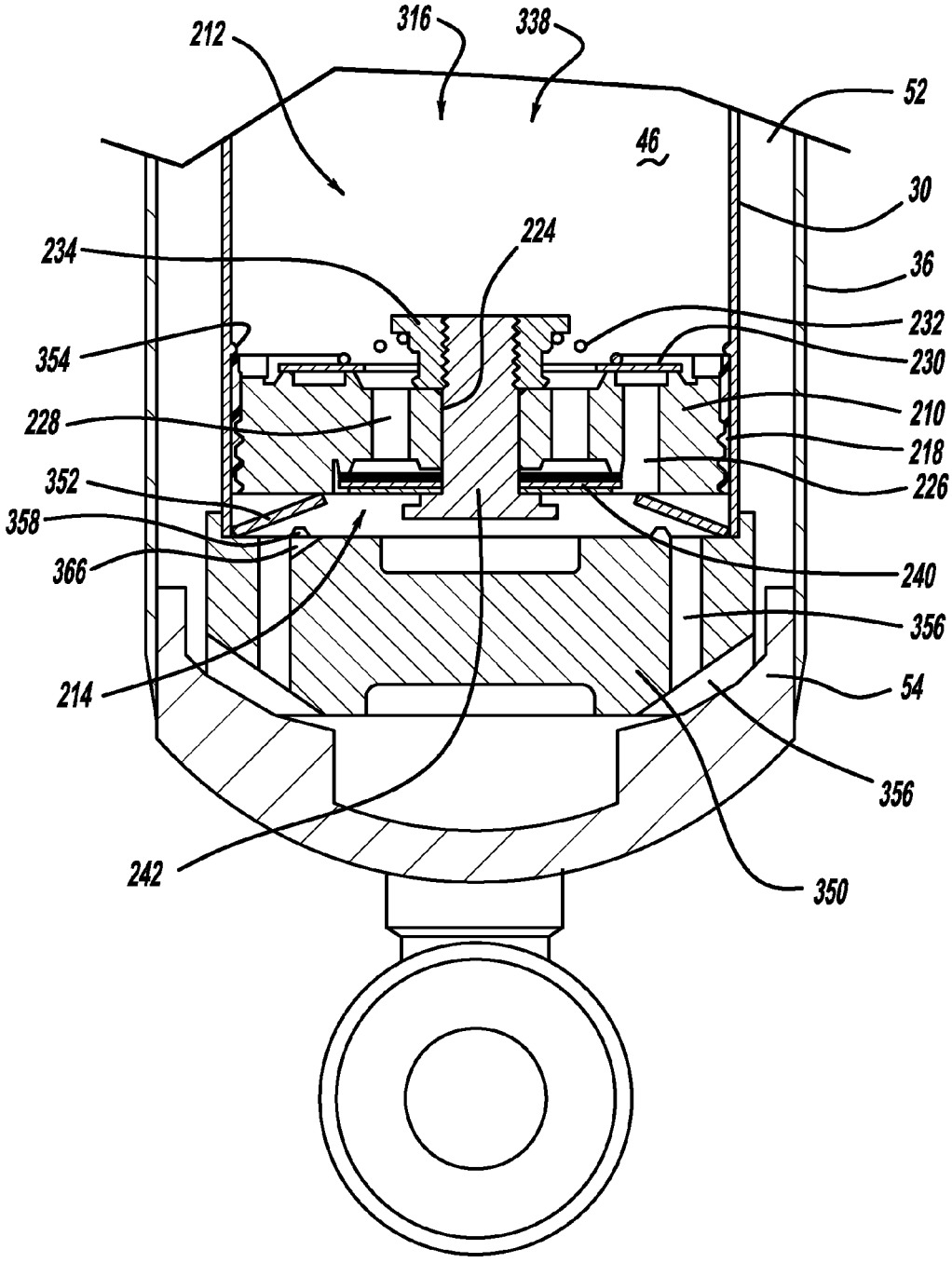
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FIG - 7

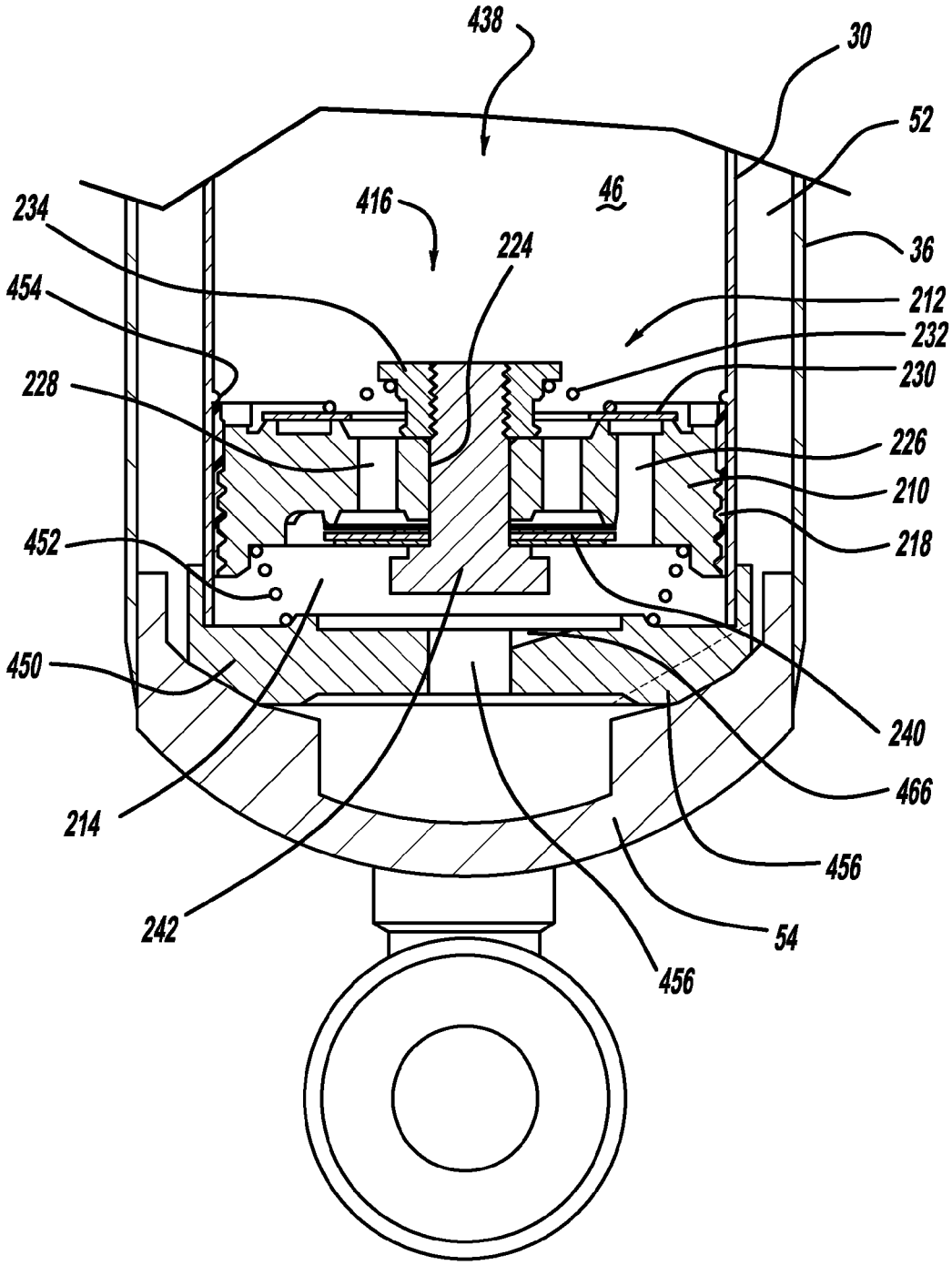
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FIG - 8

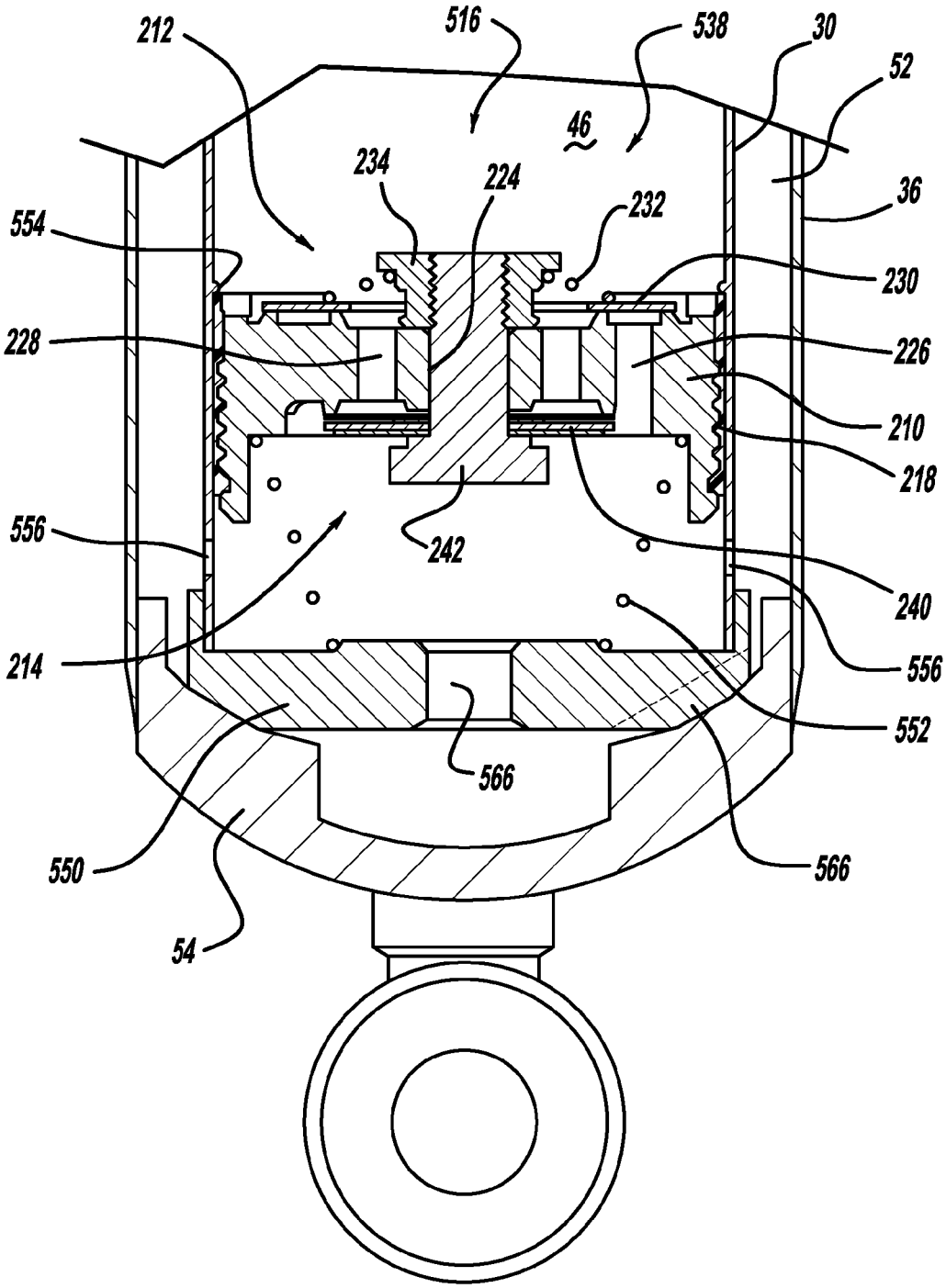
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FIG - 9

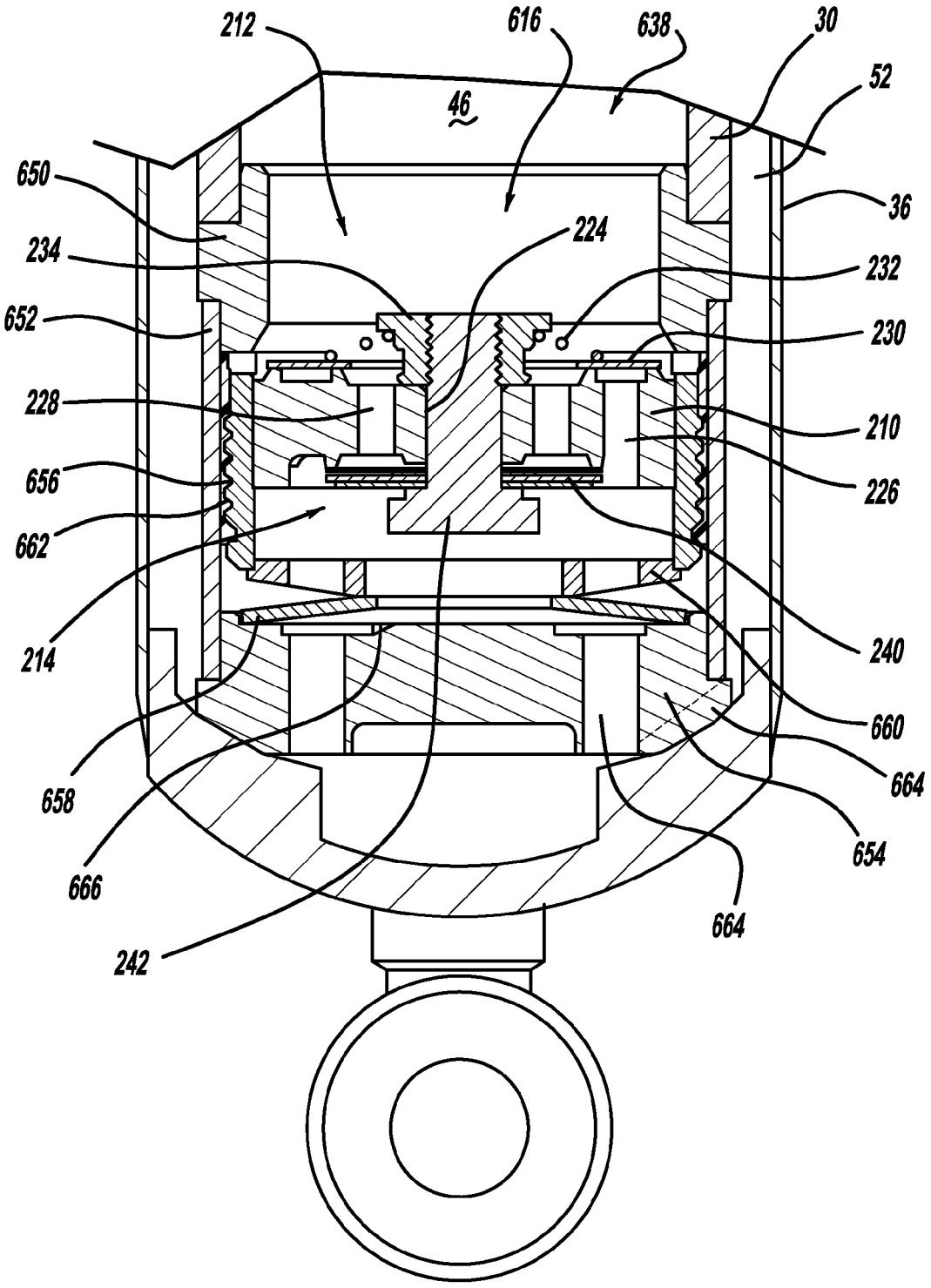
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FIG - 10

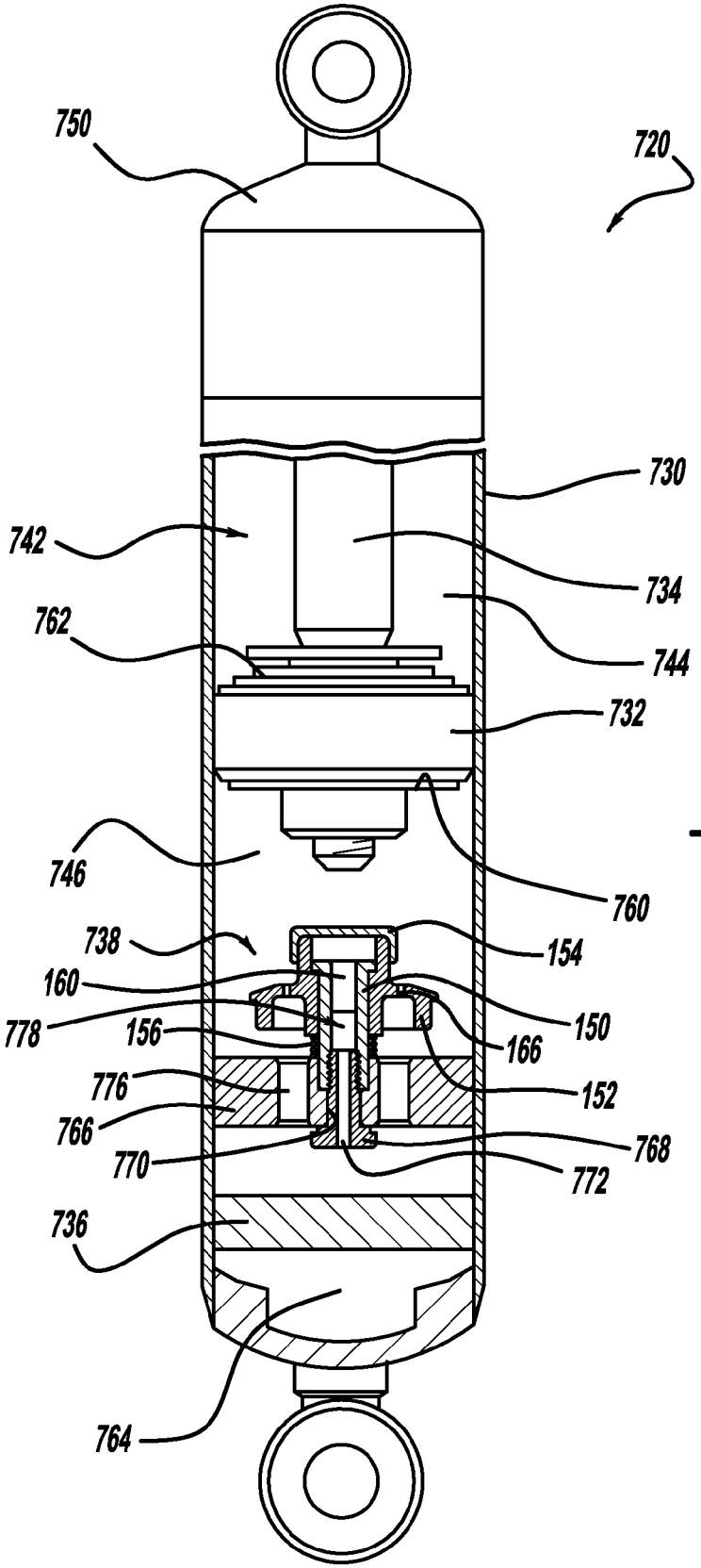
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FIG - 11

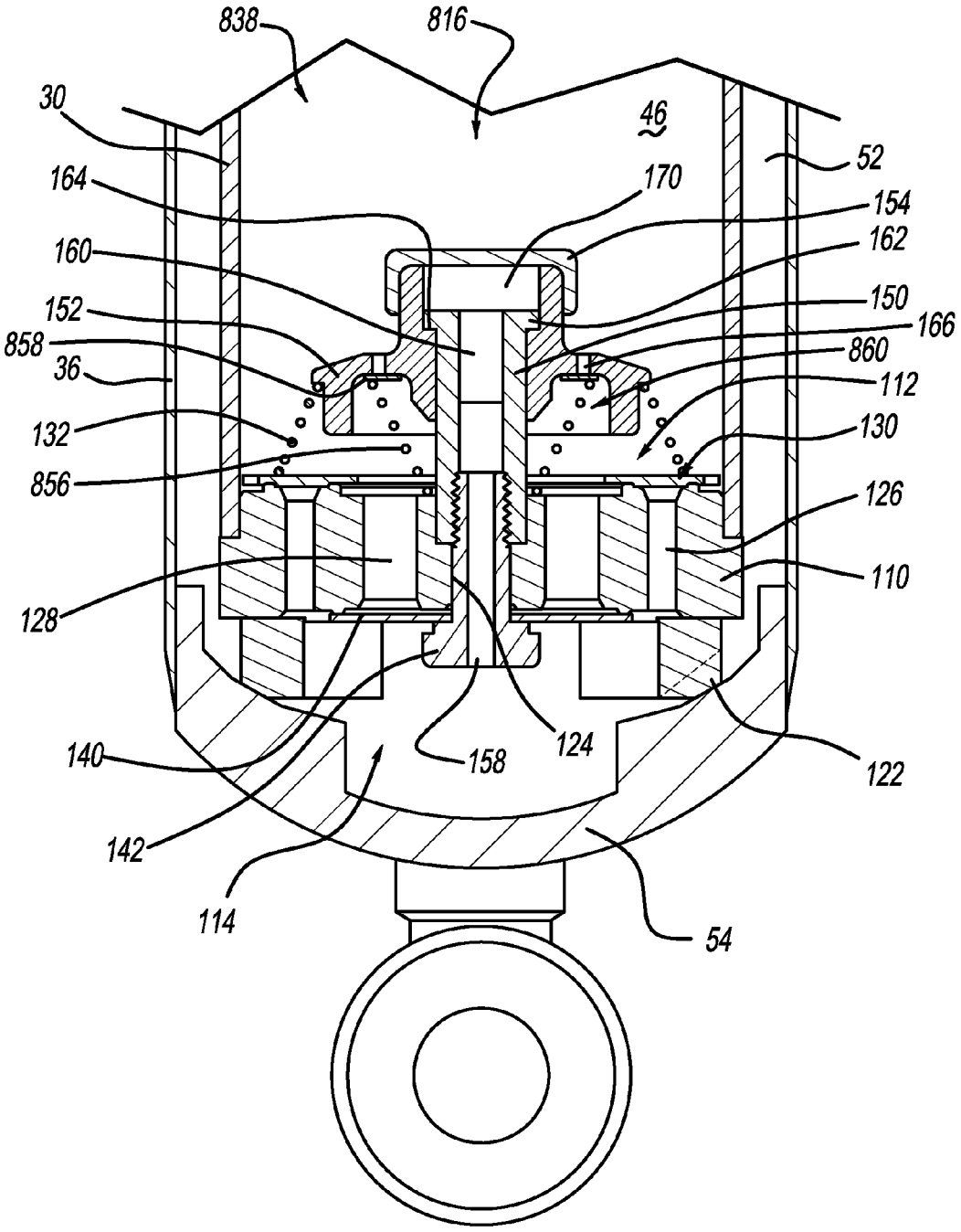
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FIG - 12

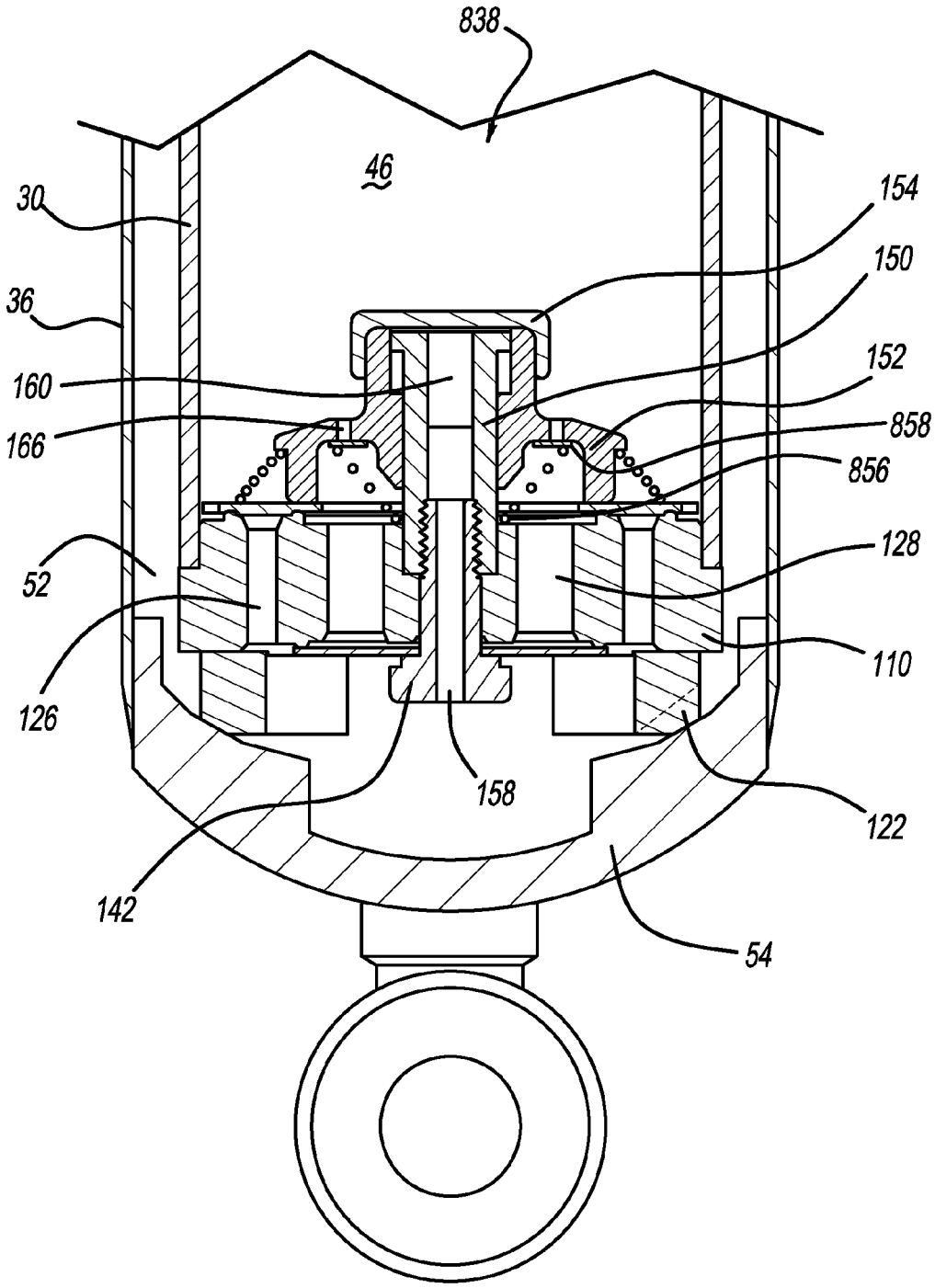
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FIG - 13

# HIGH VELOCITY COMPRESSION DAMPING VALVE

## CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation-in-part of U.S. patent application Ser. No. 12/496,964 filed on Jul. 2, 2009 which claims the benefit of Provisional U.S. Patent Application No. 61/100,321 filed Sep. 26, 2008. The entire disclosures of which are incorporated herein by reference.

## FIELD

The present disclosure relates generally to shock absorbers or dampers. More particularly, the present disclosure relates to a shock absorber or damper having a base valve assembly which includes a pressure sensitive valve assembly for high speed damping.

## BACKGROUND

This section provides background information related to the present disclosure which is not necessarily prior art.

Shock absorbers are used in conjunction with automotive suspension systems and other suspension systems to absorb unwanted vibrations which occur during movement of the suspension system. In order to absorb these unwanted vibrations, automotive shock absorbers are generally connected between the sprung (body) and the unsprung (suspension/chassis) masses of the automobile.

The most common type of shock absorbers for automobiles are the dashpot type in which a piston is located within a pressure tube and is connected to the sprung mass of the vehicle through a piston rod. The piston divides the pressure tube into an upper working chamber and a lower working chamber. Because the piston, through valving, has the ability to limit the flow of damping fluid between the upper and lower working chambers within the pressure tube when the shock absorber is compressed or extended, the shock absorber is able to produce a damping force which counteracts the vibrations which would otherwise be transmitted from the unsprung mass to the sprung mass. In a dual tube shock absorber, a fluid reservoir is defined between the pressure tube and a reserve tube which is positioned around the pressure tube. A base valve is located between the lower working chamber and the fluid reservoir to also produce a damping force which counteracts the vibration which would otherwise be transmitted from the unsprung portion to the sprung portion of the automobile during stroking of the shock absorber.

Some applications or suspension systems that are developed could benefit by utilizing a displacement sensitive damping concept, a velocity sensitive damping concept and/or an acceleration sensitive concept.

## SUMMARY

This section provides a general summary of the disclosure, and is not a comprehensive disclosure of its full scope or all of its features.

The present disclosure provides a shock absorber or damper which incorporates high speed damping by using a base valve assembly which increases the amount of damping load generated as the velocity of the piston increases during a compression stroke of the shock absorber or damper. A pressure responsive device is incorporated into the base valve assembly to increase the damping load in response to an increase in pressure of the working chamber caused by the increase in velocity of the piston in the pressure tube during a compression stroke.

Further areas of applicability will become apparent from the description provided herein. The description and specific examples in this summary are intended for purposes of illustration only and are not intended to limit the scope of the present disclosure.



## DRAWINGS

The drawings described herein are for illustrative purposes only of selected embodiments and not all possible implementations, and are not intended to limit the scope of the present disclosure.

FIG. **1** is a schematic representation of a typical automobile which incorporates the high velocity compression damping valve in accordance with the present disclosure;

FIG. **2** is a side sectional view of a shock absorber which incorporates the high velocity compression damping in accordance with the present disclosure;

FIG. **3** is an enlarged cross-sectional view of the piston assembly illustrated in FIG. **2**;

FIG. **4** is an enlarged cross-sectional view of the base valve assembly illustrated in FIG. **2** in an open position;

FIG. **5** is an enlarged cross-sectional view of the base valve assembly illustrated in FIG. **4** in a closed position;

FIG. **6** is an enlarged cross-sectional view of a base valve assembly in accordance with another embodiment of the present disclosure in an open position;

FIG. **7** is an enlarged cross-sectional view of a base valve assembly in accordance with another embodiment of the present disclosure in an open position;

FIG. **8** is an enlarged cross-sectional view of a base valve assembly in accordance with another embodiment of the present disclosure in an open position;

FIG. **9** is an enlarged cross-sectional view of a base valve assembly in accordance with another embodiment of the present disclosure in an open position;

FIG. **10** is an enlarged cross-sectional view of a base valve assembly in accordance with another embodiment of the present disclosure in an open position;

FIG. **11** is a side cross-sectional view of a monotube shock absorber which incorporates the high velocity compression damping in accordance with the present disclosure;

FIG. **12** is an enlarged cross-sectional view of a base valve assembly in accordance with another embodiment of the present disclosure in an open position; and

FIG. **13** is an enlarged cross-sectional view of the base valve assembly illustrated in FIG. **12** in a closed position.

Corresponding reference numerals indicate corresponding parts throughout the several views of the drawings.

## DETAILED DESCRIPTION

Example embodiments will now be described more fully with reference to the accompanying drawings.

The following description of the preferred embodiment(s) is merely exemplary in nature and is in no way intended to limit the invention, its application, or uses.

Referring now to the drawings in which like reference numerals designate like or corresponding parts throughout the several views; there is shown in FIG. **1** a vehicle incorporating a suspension system incorporating the shock absorbers in accordance with the present invention and which is designated generally by the reference numeral **10**. Vehicle **10** includes a rear suspension **12**, a front suspension **14** and a

body **16**. Rear suspension **12** has a transversely extending rear axle assembly (not shown) adapted to operatively support a pair of rear wheels **18** of vehicle **10**. The rear axle assembly is operatively connected to body **16** by means of a pair of shock absorbers **20** and a pair of helical coil springs **22**. Similarly, front suspension **14** includes a transversely extending front axle assembly (not shown) to operatively support a pair of front wheels **24** of vehicle **10**. The front axle assembly is operatively connected to body **16** by means of a second pair of shock absorbers **26** and by a pair of helical coil springs **28**. Shock absorbers **20** and **26** serve to dampen the relative motion of the unsprung mass (i.e., front and rear suspensions **12** and **14**, respectively) and the sprung mass (i.e., body **16**) of vehicle **10**. While vehicle **10** has been depicted as a passenger car having front and rear axle assemblies, shock absorbers **20** and **26** may be used with other types of vehicles or in other types of applications such as vehicles incorporating independent front and/or independent rear suspension systems. Further, the term "shock absorber" as used herein is meant to refer to dampers in general and thus will include MacPherson struts.

Referring now to FIG. **2**, shock absorber **20** is shown in greater detail. While FIG. **2** illustrates only shock absorber **20**, it is to be understood that shock absorber **26** also includes the base valve assembly described below for shock absorber **20**. Shock absorber **26** only differs from shock absorber **20** in the manner in which it is adapted to be connected to the sprung and unsprung masses of vehicle **10**. Shock absorber **20** comprises a pressure tube **30**, a piston assembly **32**, a piston rod **34**, a reserve tube **36** and a base valve assembly **38**.

Pressure tube **30** defines a working chamber **42**. Piston assembly **32** is slidably disposed within pressure tube **30** and divides working chamber **42** into an upper working chamber **44** and a lower working chamber **46**. A seal **48** is disposed between piston assembly **32** and pressure tube **30** to permit sliding movement of piston assembly **32** with respect to pressure tube **30** without generating undue frictional forces as well as sealing upper working chamber **44** from lower working chamber **46**. Piston rod **34** is attached to piston assembly **32** and extends through upper working chamber **44** and through end cap **50** which closes the upper end of pressure tube **30**. A sealing system seals the interface between upper end cap **50**, reserve tube **36** and piston rod **34**. The end of piston rod **34** opposite to piston assembly **32** is adapted to be secured to the sprung portion of vehicle **10**. Valving within piston assembly **32** controls the movement of fluid between upper working chamber **44** and lower working chamber **46** during movement of piston assembly **32** within pressure tube **30**. Because piston rod **34** extends only through upper working chamber **44** and not lower working chamber **46**, movement of piston assembly **32** with respect to pressure tube **30** causes a difference in the amount of fluid displaced in upper working chamber **44** and the amount of fluid displaced in lower working chamber **46**. The difference in the amount of fluid displaced is known as the "rod volume" and it flows through base valve assembly **38**.

Reserve tube **36** surrounds pressure tube **30** to define a fluid reservoir chamber **52** located between tubes **30** and **36**. The bottom end of reserve tube **36** is closed by an end cap **54** which is adapted to be connected to the unsprung portion of vehicle **10**. While end cap **54** is illustrated as a separate component, it is within the scope of the present disclosure to have end cap **54** integral with reserve tube **36**. The upper end of reserve tube **36** is attached to upper end cap **50**. Base valve assembly **38** is disposed between lower working chamber **46** and reservoir chamber **52** to control the flow of fluid between chambers **46** and **52**. When shock absorber **20** extends in length, an additional volume of fluid is needed in lower working chamber **46** due to the "rod volume" concept. Thus, fluid will flow from reservoir chamber **52** to lower working chamber **46** through base valve assembly **38** as detailed below. When shock absorber **20** compresses in length, an excess of fluid must be removed from lower working chamber **46** due to the "rod volume" concept. Thus, fluid will flow from lower working chamber **46** to reservoir chamber **52** through base valve assembly **38** as detailed below.

Referring now to FIG. **3**, piston assembly **32** comprises a piston body **60**, a compression valve assembly **62** and a rebound valve assembly **64**. Compression valve assembly **62** is assembled against a shoulder **66** on piston rod **34**. Piston body **60** is assembled against compression valve assembly **62** and rebound valve assembly **64** is assembled against piston body **60**. A nut **68** secures these components to piston rod **34**.

Piston body **60** defines a plurality of compression passages **70** and a plurality of rebound passages **72**. Seal **48** includes a plurality of ribs **74** which mate with a plurality of annular grooves **76** to restrict sliding movement of seal **48** relative to piston body **60** as piston assembly **32** slides in pressure tube **30**.

Compression valve assembly **62** comprises a retainer **78**, a valve disc **80** and a spring **82**. Retainer **78** abuts shoulder **66** on one end and piston body **60** on the other end. Valve disc **80** abuts piston body **60** and closes compression passages **70** while leaving rebound passages **72** open. Spring **82** is disposed between retainer **78** and valve disc **80** to bias valve disc **80** against piston body **60**. During a compression stroke, fluid in lower working chamber **46** is pressurized causing fluid pressure to react against valve disc **80**. When the fluid pressure against valve disc **80** overcomes the biasing load of spring **82**, valve disc **80** separates from piston body **60** to open compression passages **70** and allow fluid flow from lower working chamber to upper working chamber. Typically spring **82** only exerts a light load on valve disc **80** and compression valve assembly **62** acts like a check valve between chambers **46** and **44**. The damping characteristics for shock absorber **20** during a compression stroke of shock absorber **20** are controlled by base valve assembly **38** which accommodates the flow of fluid from lower working chamber **46** to reservoir chamber **52** due to the "rod volume" concept as detailed below. During a rebound stroke, compression passages **70** are closed by valve disc **80**.

Rebound valve assembly **64** comprises a spacer **84**, a plurality of valve discs **86**, a retainer **88** and a spring **90**. Spacer **84** is threadingly received on piston rod **34** and is disposed between piston body **60** and nut **68**. Spacer **84** retains piston body **60** and compression valve assembly **62** while permitting the tightening of nut **68** without compressing either valve disc **80** or valve discs **86**. Retainer **78**, piston body **60** and spacer **84** provide a continuous solid connection between shoulder **66** and nut **68** to facilitate the tightening and securing of nut **68** to spacer **84** and thus to piston rod **34**. Valve discs **86** are slidingly received on spacer **84** and abut piston body **60** to close rebound passages **72** while leaving compression passages **70** open. Retainer **88** is also slidingly received on spacer **84** and it abuts valve discs **86**. Spring **90** is assembled over spacer **84** and is disposed between retainer **88** and nut **68** which is threadingly received on spacer **84**. Spring **90** biases retainer **88** against valve discs **86** and valve discs **86** against piston body **60**. The plurality of valve discs **86** comprise a bleed disc **92**, a valve disc **94**, a spacer disc **96** and a fulcrum disc **98**. Bleed disc **92** includes at least one slot **100** which permits a limited amount of bleed flow bypassing rebound valve assembly **64**. Fulcrum disc **98** provides a fulcrum or bending point for bleed disc **92**, valve disc **94** and spacer disc

96. When fluid pressure is applied to discs **92** and **94**, they will elastically deflect at the outer peripheral edge of spacer disc **96** and fulcrum disc **98** to open rebound valve assembly **64**. A shim **102** is located between nut **68** and spring **90** to control the preload for spring **90** and thus the blow off pressure as described below. Thus, the calibration for the blow off feature of rebound valve assembly **64** is separate from the calibration for compression valve assembly **62**.

During a rebound stroke, fluid in upper working chamber **44** is pressurized causing fluid pressure to react against valve discs **86**. When the fluid pressure reacting against valve discs **86** overcomes the bending load for valve discs **86**, valve discs **86** elastically deflect opening rebound passages **72** allowing fluid flow from upper working chamber **44** to lower working chamber **46**. The strength of valve discs **86** and the size of rebound passages will determine the damping characteristics for shock absorber **20** in rebound. Prior to the deflection of valve discs **86**, a controlled amount of fluid flows from upper working chamber **44** to lower working chamber **46** through slot **100** to provide low speed tunability. When the fluid pressure within upper working chamber **44** reaches a predetermined level, the fluid pressure will overcome the biasing load of spring **90** causing axial movement of retainer **88** and the plurality of valve discs **86**. The axial movement of retainer **88** and valve discs **86** fully opens rebound passages **72** thus allowing the passage of a significant amount of damping fluid creating a blowing off of the fluid pressure which is required to prevent damage to shock absorber **20** and/or vehicle **10**. Additional fluid required to be added to lower working chamber **46** due to the "rod volume" concept will flow through base valve assembly **38**.

Referring now to FIGS. **4** and **5**, base valve assembly **38** is illustrated. Base valve assembly **38** comprises a cylinder end **110**, a rebound valve assembly **112**, a compression valve assembly **114** and a pressure sensitive valve assembly **116**. Cylinder end **110** is attached to pressure tube **30** and separates lower working chamber **46** from reservoir chamber **52**. Cylinder end **110** engages end cap **54** and it defines a plurality of fluid passages **122** open to reservoir chamber **52**. Cylinder end **110** defines a central passage **124** extending between lower working chamber **46** and reservoir chamber **52** through fluid passages **122**, a plurality of rebound fluid passages **126** extending between lower working chamber **46** and reservoir chamber **52** through fluid passages **122** and a plurality of compression fluid passages **128** extending between lower working chamber **46** and reservoir chamber **52** through fluid passages **122**.

Rebound valve assembly **112** comprises one or more valve discs **130** and a valve spring **132**. Valve discs **130** close the plurality of rebound fluid passages **126** and valve spring **132** is disposed between pressure sensitive valve assembly **116** and valve disc **130** to bias valve disc **130** against cylinder end **110**. During a rebound stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from reservoir chamber **52** to lower working chamber **46**. The rebound stroke reduces the fluid pressure within lower working chamber **46** and the fluid pressure within reservoir chamber **52** will exceed the fluid pressure within lower working chamber **46**. The fluid pressure within reservoir chamber **52** will react against valve disc **130** and when the load on valve disc **130** from the fluid pressure exceeds the biasing load of valve spring **132**, valve disc **130** will unseat from cylinder end **110** and fluid will flow from reservoir chamber **52** through fluid passages **122**, through rebound fluid passages **126** and into lower working chamber **46**. Valve spring **132** is designed to exert a minimum load against valve disc **130** such that rebound valve assembly **112** acts like a check valve during a rebound stroke and does not substantially contribute to the damping loads for shock absorber **20**. The damping load during a rebound stroke for shock absorber **20** is created by rebound valve assembly **64** of piston assembly **32**.

Compression valve assembly **114** comprises one or more valve discs **140** and a bolt **142**. Valve discs **140** close the plurality of compression fluid passages **128** and bolt **142** threadingly engages pressure sensitive valve assembly **116** to secure valve disc **140** against cylinder end **110**. During a compression stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from lower working chamber **46** to reservoir chamber **52**. During the compression stroke, fluid pressure in lower working chamber **46** increases and this fluid pressure reacts against valve discs **140**. As the fluid pressure within lower working chamber **46** increases, the fluid pressure reacts against valve discs **140** and eventually valve discs **140** will deflect to open compression fluid passages **128**. Fluid will flow from lower working chamber **46**, through compression fluid passages **128**, through fluid passages **122** and into reservoir chamber **52**. The damping load during a compression stroke is created by compression valve assembly **114**. As described above, compression valve assembly **62** of piston assembly **32** acts like a check valve and does not substantially contribute to the damping loads for shock absorber **20**. Compression valve assembly **114** is a normally closed compression valve assembly which is opened by the pressure differential between lower working chamber **46** and reservoir chamber **52**. The flow through compression valve assembly **114** is directly proportional to the pressure differential. The greater the pressure differential, the greater deflection of valve discs **140** and the greater the flow through compression valve assembly **114**.

Pressure sensitive valve assembly **116** is a pressure actuated valve assembly which comprises cylinder end **110**, a stem **150**, a spool **152**, a spool cap **154** and a valve spring **156**. Stem **150** is disposed within central passage **124** and is secured to cylinder end **110** by bolt **142** of compression valve assembly **114**. Bolt **142** defines a central fluid passage **158** and stem **150** defines a central fluid passage **160** to provide for a pressure drop as described below.

Spool **152** is slidingly received over stem **150**. Upward movement of spool **152** on stem **150** is limited by a flange **162** on stem **150** which engages a shoulder **164** defined by spool **152**. Valve spring **132** of rebound valve assembly **112** and valve spring **156** of pressure sensitive valve assembly **116** biases shoulder **164** of spool **152** against flange **162** of stem **150** to allow fluid to flow from lower working chamber **46** into the plurality of compression fluid passages **128**. Spool cap **154** is secured to spool **152**. Spool **152** defines one or more holes **166**.

During a compression stroke, fluid pressure within lower working chamber **46** acts against spool **152** and spool cap **154** of pressure sensitive valve assembly **116**. The fluid pressure within reservoir chamber **52** acts against spool **152** and spool cap **154** of pressure sensitive valve assembly **116**. The reservoir fluid pressure is channeled to spool **152** and spool cap **154** through fluid passages **122**, **158** and **160**. The biasing of valve spring **132** and valve spring **156** allows for the normal flow of fluid through compression valve assembly **114** as described above as long as the pressure difference across spool **152** does not generate sufficient load to overcome the biasing load of valve spring **132** and valve spring **156**. Once the pressure differential acting on spool **152** exceeds the biasing load of valve spring **132** and valve spring **156**, spool **152** will slide downward on stem **150** and close or prohibit fluid flow from lower working chamber **46** to the plurality of compression fluid passages **128** as illustrated in FIG. **5**. Once

the fluid pressure across spool **152** reduces, valve spring **132** and valve spring **156** will again bias spool **152** upward against flange **162**. When spool **152** closes or prohibits fluid flow, the fluid pressure in lower working chamber **46** exponentially increases and the only flow between lower working chamber **46** and reservoir chamber **58** is through the one or more holes **166** and compression valve assembly **114**. The area of the one or more holes **166** and the instantaneous velocity of piston assembly **32** will define the final damping forces achieved. The increase in fluid pressure within lower working chamber **46** is a function of the velocity of piston assembly **32** and thus pressure sensitive valve assembly **116** is a pressure sensitive valve which opens and closes based upon the velocity of piston assembly **32**. Pressure sensitive valve assembly **116** is a normally open compression valve assembly which is closed by the pressure differential between lower working chamber **46** and reservoir chamber **52** where the pressure differential is determined by the velocity of piston assembly **32**.

The movement of spool **152** can be controlled or damped by controlling the diameter of central fluid passage **158** of bolt **142**. As illustrated in FIG. **4**, a fluid chamber **170** is located above bolt **142**. This volume must be displaced through central fluid passage **158** in order for spool **152** to move downward. By controlling the diameter of central fluid passage **158** the period of time that it takes spool **152** to move downward can be controlled. Thus, a damping effect can be achieved in regard to this motion of spool **152**.

Pressure sensitive valve assembly **116** can also be converted to an acceleration sensitive valve assembly. By eliminating central fluid passage **158** and eliminating spool cap **154**, pressure sensitive valve assembly **116** would be converted from a pressure sensitive valve assembly to an acceleration sensitive valve assembly. In this configuration, motion of spool **152** would be defined by the mass of spool **152** and the design for valve spring **156**. These specifications can be tuned to a specific desired frequency and will provide a similar increase in damping force once closed. Final damping force will be defined by providing bypass passage **166** as previously discussed.

Referring now to FIG. **6**, base valve assembly **238** is illustrated. Base valve assembly **238** comprises a piston **210**, a rebound valve assembly **212**, a compression valve assembly **214** and a pressure sensitive valve assembly **216**. Piston **210** is slidingly received in pressure tube **30** and separates lower working chamber **46** from reservoir chamber **52**. Piston **210** defines a central passage **224** extending between lower working chamber **46** and reservoir chamber **52**, a plurality of rebound fluid passages **226** extending between lower working chamber **46** and reservoir chamber **52** and a plurality of compression fluid passages **228** extending between lower working chamber **46** and reservoir chamber **52**.

Rebound valve assembly **212** comprises one or more valve discs **230** and a valve spring **232** and a nut **234**. Valve disc or valve discs **230** closes the plurality of rebound fluid passages **226** and valve spring **232** is disposed between nut **234** and valve disc **230** to bias valve disc **230** against piston **210**. Fluid access to compression fluid passages **228** is provided by a plurality of apertures which extend through valve disc **230**. During a rebound stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from reservoir chamber **52** to lower working chamber **46**. The rebound stroke reduces the fluid pressure within lower working chamber **46** and the fluid pressure within reservoir chamber **52** will exceed the fluid pressure within lower working chamber **46**. The fluid pressure within reservoir chamber **52** will react against valve disc **230** and when the load on valve disc **230** from the fluid pressure exceeds the biasing load of valve spring **232**, valve disc **230** will unseat from piston **210** and fluid will flow from reservoir chamber **52**, through rebound fluid passages **226** and into lower working chamber **46**. Valve spring **232** is designed to exert a minimum load against valve disc **230** such that rebound valve assembly **212** acts like a check valve during a rebound stroke and does not substantially contribute to the damping loads for shock absorber **20**. The damping load during a rebound stroke for shock absorber **20** is created by rebound valve assembly **64** of piston assembly **32**.

Compression valve assembly **214** comprises one or more valve discs **240** and a bolt **242**. Valve discs **240** close the plurality of compression fluid passages **228** and bolt **242** threadingly engages nut **234** to secure valve disc **240** against piston **210**. During a compression stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from lower working chamber **46** to reservoir chamber **52**. During the compression stroke, fluid pressure in lower working chamber **46** increases and this fluid pressure reacts against valve discs **240**. As the fluid pressure within lower working chamber **46** increases, the fluid pressure reacts against valve discs **240** and eventually valve discs **240** will deflect to open compression fluid passages **228**. Fluid will flow from lower working chamber **46**, through fluid passages **228** and into reservoir chamber **52**. The damping load during a compression stroke is created by compression valve assembly **214**. As described above, compression valve assembly **62** of piston assembly **32** acts like a check valve and does not substantially contribute to the damping loads for shock absorber **20**. Compression valve assembly **214** is a normally closed compression valve assembly which is opened by the pressure differential between lower working chamber **46** and reservoir chamber **52**. The flow through compression valve assembly **214** is directly proportional to the pressure differential. The greater the pressure differential, the greater deflection of valve discs **140** and the greater the flow through compression valve assembly **214**.

Pressure sensitive valve assembly **216** comprises piston **210**, a cylinder end **250** and a biasing spring **252**. Cylinder end **250** is attached to pressure tube **30** and it engages end cap **54**. Piston **210** is slidably disposed within pressure tube **30** and slides between cylinder end **250** and a stop **254**. Biasing spring **252** urges piston **210** towards stop **254**. Cylinder end **250** defines one or more apertures **256** which allow fluid flow between lower working chamber **46** and reservoir chamber **52**.

During a compression stroke, fluid pressure within lower working chamber **46** acts against the upper side of piston **210**. The fluid pressure within reservoir chamber **52** acts against the lower side of piston **210**. The biasing load of biasing spring **252** allows for the normal flow of fluid through compression valve assembly **214** as described above as long as the pressure differential across piston **210** does not generate sufficient load to overcome the biasing load of biasing spring **252**. Once the pressure differential across piston **210** generates sufficient load to overcome the biasing load of biasing spring **252**, piston **210** will slide downward in pressure tube **30**. As piston **210** approaches cylinder end **250**, compression valve assembly **214** will contact a land **258** on cylinder end **250** and close or prohibit fluid flow from lower working chamber **46** through apertures **256** to reservoir chamber **52**. When the fluid pressure difference across piston **210** reduces, biasing spring **252** will again bias piston **210** against stop **254**. As illustrated, valve discs **240** contact land **258** but the present invention is not limited to this concept as other components could prohibit fluid flow. Pressure sensitive valve assembly **216** is a normally open compression valve assembly which is closed by the pressure differential between lower working

chamber **46** and reservoir chamber **52** where the pressure differential is determined by the velocity of piston assembly **32**.

The fluid pressure in lower working chamber **46** exponentially increases and the only flow between lower working chamber **46** and reservoir chamber **52** is through a bypass **266** defined by compression valve assembly **214** or by compression valve assembly **214** and pressure sensitive valve assembly **216**. Bypass **266** can include a passage around or through valve discs **240** or a bypass passage defined by piston **210** and cylinder end **250**. The area of bypass **266** and the instantaneous velocity of piston assembly **32** will define the final damping forces achieved. The increase in fluid pressure within lower working chamber **46** is function of the velocity of piston assembly **32** and thus, pressure sensitive valve assembly **216** is a pressure sensitive valve which opens and closes based upon the velocity of piston assembly **32**.

Referring now to FIG. **7**, base valve assembly **338** is illustrated. Base valve assembly **338** comprises piston **210**, rebound valve assembly **212**, compression valve assembly **214** and a pressure sensitive valve assembly **316**. Piston **210** is slidingly received in pressure tube **30** and separates lower working chamber **46** from reservoir chamber **52**. Piston **210** defines central passage **224** extending between lower working chamber **46** and reservoir chamber **52**, the plurality of rebound fluid passages **226** extending between lower working chamber **46** and reservoir chamber **52** and the plurality of compression fluid passages **228** extending between lower working chamber **46** and reservoir chamber **52**.

Rebound valve assembly **212** comprises the one or more valve discs **230**, valve spring **232** and nut **234**. Valve disc or valve discs **230** close the plurality of rebound fluid passages **226** and valve spring **232** is disposed between nut **234** and valve disc **230** to bias valve disc **230** against piston **210**. Fluid access to compression fluid passages **228** is provided by a plurality of apertures which extend through valve disc **230**. During a rebound stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from reservoir chamber **52** to lower working chamber **46**. The rebound stroke reduces the fluid pressure within lower working chamber **46** and the fluid pressure within reservoir chamber **52** will exceed the fluid pressure within lower working chamber **46**. The fluid pressure within reservoir chamber **52** will react against valve disc **230** and when the load on valve disc **230** from the fluid pressure exceeds the biasing load of valve spring **232**, valve disc **230** will unseat from piston **210** and fluid will flow from reservoir chamber **52**, through rebound fluid passages **226** and into lower working chamber **46**. Valve spring **232** is designed to exert a minimum load against valve disc **230** such that rebound valve assembly **212** acts like a check valve during a rebound stroke and does not substantially contribute to the damping loads for shock absorber **20**. The damping load during a rebound stroke for shock absorber **20** is created by rebound valve assembly **64** of piston assembly **32**.

Compression valve assembly **214** comprises the one or more valve discs **240** and bolt **242**. Valve discs **240** close the plurality of compression fluid passages **228** and bolt **242** threadingly engages nut **234** to secure valve disc **240** against piston **210**. During a compression stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from lower working chamber **46** to reservoir chamber **52**. During the compression stroke, fluid pressure in lower working chamber **46** increases and this fluid pressure reacts against valve discs **240**. As the fluid pressure within lower working chamber **46** increases, the fluid pressure reacts against valve discs **240** and eventually valve discs **240** will deflect to open compression fluid passages **228**. Fluid will flow from lower working chamber **46**, through fluid passages **228** and into reservoir chamber **52**. The damping load during a compression stroke is created by compression valve assembly **214**. As described above, compression valve assembly **62** of piston assembly **32** acts like a check valve and does not substantially contribute to the damping loads for shock absorber **20**. Compression valve assembly **214** is a normally closed compression valve assembly which is opened by the pressure differential between lower working chamber **46** and reservoir chamber **52**. The flow through compression valve assembly **214** is directly proportional to the pressure differential. The greater the pressure differential, the greater deflection of valve discs **140** and the greater the flow through compression valve assembly **214**.

Pressure sensitive valve assembly **316** comprises a cylinder end **350** and a biasing spring **352**. Cylinder end **350** is attached to pressure tube **30** and it engages end cap **54**. Piston **210** is slidably disposed within pressure tube **30** and slides between cylinder end **350** and a stop **354**. Biasing spring **352** urges piston **210** towards a stop **354**. Cylinder end **350** defines one or more apertures **356** which allow fluid flow between lower working chamber **46** and reservoir chamber **52**.

During a compression stroke, fluid pressure within lower working chamber **46** acts against the upper side of piston **210**. The fluid pressure within reservoir chamber **52** acts against the lower side of piston **210**. The biasing load of biasing spring **352** allows for the normal flow of fluid through compression valve assembly **214** as described above as long as the pressure differential across piston **210** does not generate sufficient load to overcome the biasing load of biasing spring **352**. Once the pressure differential across piston **210** generates sufficient load to overcome the biasing load of biasing spring **352**, piston **210** will slide down in pressure tube **30**. As piston **210** approaches cylinder end **350**, biasing spring **352** will interface with a sealing land **358** on cylinder end **350** to close or prohibit fluid flow from lower working chamber **46** to reservoir chamber **52** through apertures **356**. When the fluid pressure difference across piston **210** reduces, biasing spring **352** will again bias piston **210** against stop **354**. As illustrated, biasing spring **352** interfaces with cylinder end **350** but the present disclosure is not limited to this concept as other components could prohibit the fluid flow. Pressure sensitive valve assembly **316** is a normally open compression valve assembly which is closed by the pressure differential between lower working chamber **46** and reservoir chamber **52** where the pressure differential is determined by the velocity of piston assembly **32**.

The fluid pressure in lower working chamber **46** exponentially increases and the only flow between lower working chamber **46** and reservoir chamber **52** is through a bypass **366** defined by compression valve assembly **214** or by compression valve assembly **214** and pressure sensitive valve assembly **316**. Bypass **366** can include a passage around or through cylinder end **350**. The area of bypass **366** and the instantaneous velocity of piston assembly **32** will define the final damping forces achieved. The increase in fluid pressure within lower working chamber **46** is a function of the velocity of piston assembly **32** and thus pressure sensitive valve assembly **316** is a pressure sensitive valve which opens and closes based upon the velocity of piston assembly **32**.

Referring now to FIG. **8**, base valve assembly **438** is illustrated. Base valve assembly **438** comprises piston **210**, rebound valve assembly **212**, compression valve assembly **214** and a pressure sensitive valve assembly **416**. Piston **210** is slidingly received in pressure tube **30** and separates lower working chamber **46** from reservoir chamber **52**. Piston **210** defines central passage **224** extending between lower work-

ing chamber **46** and reservoir chamber **52**, the plurality of rebound fluid passages **226** extending between lower working chamber **46** and reservoir chamber **52** and the plurality of compression fluid passages **228** extending between lower working chamber **46** and reservoir chamber **52**.

Rebound valve assembly **212** comprises the one or more valve discs **230** valve spring **232** and nut **234**. Valve discs **230** close the plurality of rebound fluid passages **226** and valve spring **232** is disposed between nut **234** and valve disc **230** to bias valve disc **230** against piston **210**. Fluid access to compression fluid passages **228** is provided by a plurality of apertures which extend through valve disc **230**. During a rebound stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from reservoir chamber **52** to lower working chamber **46**. The rebound stroke reduces the fluid pressure within lower working chamber **46** and the fluid pressure within reservoir chamber **52** will exceed the fluid pressure within lower working chamber **46**. The fluid pressure within reservoir chamber **52** will react against valve disc **230** and when the load on valve disc **230** from the fluid pressure exceeds the biasing load of valve spring **232**, valve disc **230** will unseat from piston **210** and fluid will flow from reservoir chamber **52**, through rebound fluid passages **226** and into lower working chamber **46**. Valve spring **232** is designed to exert a minimum load against valve disc **230** such that rebound valve assembly **212** acts like a check valve during a rebound stroke and does not substantially contribute to the damping loads for shock absorber **20**. The damping load during a rebound stroke for shock absorber **20** is created by rebound valve assembly **64** of piston assembly **32**.

Compression valve assembly **214** comprises the one or more valve discs **240** and bolt **242**. Valve discs **240** close the plurality of compression fluid passages **228** and bolt **242** threadingly engages nut **234** to secure valve disc **240** against piston **210**. During a compression stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from lower working chamber **46** to reservoir chamber **52**. During the compression stroke, fluid pressure in lower working chamber **46** increases and this fluid pressure reacts against valve discs **240**. As the fluid pressure within lower working chamber **46** increases, the fluid pressure reacts against valve discs **240** and eventually valve discs **240** will deflect to open compression fluid passages **228**. Fluid will flow from lower working chamber **46**, through fluid passages **228** and into reservoir chamber **52**. The damping load during a compression stroke is created by compression valve assembly **214**. As described above, compression valve assembly **62** of piston assembly **32** acts like a check valve and does not substantially contribute to the damping loads for shock absorber **20**. Compression valve assembly **214** is a normally closed compression valve assembly which is opened by the pressure differential between lower working chamber **46** and reservoir chamber **52**. The flow through compression valve assembly **214** is directly proportional to the pressure differential. The greater the pressure differential, the greater deflection of valve discs **240** and the greater the flow through compression valve assembly **214**.

Pressure sensitive valve assembly **416** comprises piston **210**, a cylinder end **450** and a biasing spring **452**. Cylinder end **450** is attached to pressure tube **30** and it engages end cap **54**. Piston **210** is slidably disposed within pressure tube **30** and slides between cylinder end **450** and a stop **454**. Biasing spring **452** urges piston **210** towards stop **454**. Cylinder end **450** defines one or more apertures **456** which allow fluid flow between lower working chamber **46** and reservoir chamber **52**.

During a compression stroke, fluid pressure within lower working chamber **46** acts against the upper side of piston **210**. The fluid pressure within reservoir chamber **52** acts against the lower side of piston **210**. The biasing load of biasing spring **452** allows for the normal flow of fluid through compression valve assembly **214** as described above as long as the pressure differential across piston **210** does not generate sufficient load to overcome the biasing load of biasing spring **452**. Once the pressure differential across piston **210** generates sufficient load to overcome the biasing load of biasing spring **452**, piston **210** will slide downward in pressure tube **30**. As piston **210** approaches cylinder end **450**, bolt **242** will contact cylinder end **450** and close or prohibit fluid flow from lower working chamber **46** through apertures **456** to reservoir chamber **52**. When the fluid pressure difference across piston **210** reduces, biasing spring **452** will again bias piston **210** against stop **454**. As illustrated, bolt **242** contacts cylinder end **450** but the present invention is not limited to this concept as other components could prohibit fluid flow. Pressure sensitive valve assembly **416** is a normally open compression valve assembly which is closed by the pressure differential between lower working chamber **46** and reservoir chamber **52** where the pressure differential is determined by the velocity of piston assembly **32**.

The fluid pressure in lower working chamber **46** exponentially increases and the only flow between lower working chamber **46** and reservoir chamber **52** is through a bypass **466** defined by compression valve assembly **214** or by compression valve assembly **214** and pressure sensitive valve assembly **216**. Bypass **466** can include a passage around or through cylinder end **450**. The area of bypass **466** and the instantaneous velocity of piston assembly **32** will define the final damping forces achieved. The increase in fluid pressure within lower working chamber **46** is function of the velocity of piston assembly **32** and thus, pressure sensitive valve assembly **416** is a pressure sensitive valve which opens and closes based upon the velocity of piston assembly **32**.

Referring now to FIG. **9**, base valve assembly **538** is illustrated. Base valve assembly **538** comprises piston **210**, rebound valve assembly **212**, compression valve assembly **214** and a pressure sensitive valve assembly **516**. Piston **210** is attached to pressure tube **30** and separates lower working chamber **46** from reservoir chamber **52**. Piston **210** defines central passage **224** extending between lower working chamber **46** and reservoir chamber **52**, the plurality of rebound fluid passages **226** extending between lower working chamber **46** and reservoir chamber **52** and the plurality of compression fluid passages **228** extending between lower working chamber **46** and reservoir chamber **52**.

Rebound valve assembly **212** comprises the one or more valve discs **230**, valve spring **232** and nut **234**. Valve discs **230** close the plurality of rebound fluid passages **226** and valve spring **232** is disposed between nut **234** and valve disc **230** to bias valve disc **230** against piston **210**. Fluid access to compression fluid passages **228** is provided by a plurality of apertures which extend through valve disc **230**. During a rebound stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from reservoir chamber **52** to lower working chamber **46**. The rebound stroke reduces the fluid pressure within lower working chamber **46** and the fluid pressure within reservoir chamber **52** will exceed the fluid pressure within lower working chamber **46**. The fluid pressure within reservoir chamber **52** will react against valve disc **230** and when the load on valve disc **230** from the fluid pressure exceeds the biasing load of valve spring **232**, valve disc **230** will unseat from piston **210** and fluid will flow from reservoir chamber **52**, through rebound fluid passages **226** and into

lower working chamber **46**. Valve spring **232** is designed to exert a minimum load against valve disc **230** such that rebound valve assembly **212** acts like a check valve during a rebound stroke and does not substantially contribute to the damping loads for shock absorber **20**. The damping load during a rebound stroke for shock absorber **20** is created by rebound valve assembly **64** of piston assembly **32**.

Compression valve assembly **214** comprises the one or more valve discs **240** and bolt **242**. Valve discs **240** close the plurality of compression fluid passages **228** and bolt **242** threadingly engages nut **234** to secure valve disc **240** against cylinder end **250**. During a compression stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from lower working chamber **46** to reservoir chamber **52**. During the compression stroke, fluid pressure in lower working chamber **46** increases and this fluid pressure reacts against valve discs **240**. As the fluid pressure within lower working chamber **46** increases, the fluid pressure reacts against valve discs **240** and eventually valve discs **240** will deflect to open compression fluid passages **228**. Fluid will flow from lower working chamber **46**, through fluid passages **228** and into reservoir chamber **52**. The damping load during a compression stroke is created by compression valve assembly **214**. As described above, compression valve assembly **62** of piston assembly **32** acts like a check valve and does not substantially contribute to the damping loads for shock absorber **20**. Compression valve assembly **214** is a normally closed compression valve assembly which is opened by the pressure differential between lower working chamber **46** and reservoir chamber **52**. The flow through compression valve assembly **214** is directly proportional to the pressure differential. The greater the pressure differential, the greater deflection of valve discs **140** and the greater the flow through compression valve assembly **214**.

Pressure sensitive valve assembly **516** comprises piston **210**, a cylinder end **550** and a biasing spring **552**. Cylinder end **550** is attached to pressure tube **30** and it engages end cap **54**. Piston **210** is slidably disposed within pressure tube **30** and slides between cylinder end **550** and a stop **554**. Biasing spring **552** urges piston **210** towards stop **554**. Pressure tube **30** defines one or more apertures **556** which allow fluid flow between lower working chamber **46** and reservoir chamber **52**.

During a compression stroke, fluid pressure within lower working chamber **46** acts against the upper side of piston **210**. The fluid pressure within reservoir chamber **52** acts against the lower side of piston **210**. The biasing load of biasing spring **552** allows for the normal flow of fluid through compression valve assembly **214** as described above as long as the pressure differential across piston **210** does not generate sufficient load to overcome the biasing load of biasing spring **552**. Once the pressure differential across piston **210** generates sufficient load to overcome the biasing load of biasing spring **552**, piston **210** will slide downward in pressure tube **30**. As piston **210** approaches cylinder end **550**, piston **210** will begin to cover apertures **556** and close or prohibit fluid flow from lower working chamber **46** through apertures **556** to reservoir chamber **52**. When the fluid pressure difference across piston **210** reduces, biasing spring **552** will again bias piston **210** against stop **554**. Pressure sensitive valve assembly **516** is a normally open compression valve assembly which is closed by the pressure differential between lower working chamber **46** and reservoir chamber **52** where the pressure differential is determined by the velocity of piston assembly **32**.

The fluid pressure in lower working chamber **46** exponentially increases and the only flow between lower working chamber **46** and reservoir chamber **52** is through a bypass **566** defined by compression valve assembly **214** or by compression valve assembly **214** and pressure sensitive valve assembly **216**. Bypass **566** can include a bypass passage defined by piston **210** and pressure tube **30**. The area of bypass **566** and the instantaneous velocity of piston assembly **32** will define the final damping forces achieved. The increase in fluid pressure within lower working chamber **46** is function of the velocity of piston assembly **32** and thus, pressure sensitive valve assembly **516** is a pressure sensitive valve which opens and closes based upon the velocity of piston assembly **32**.

Referring now to FIG. **10**, base valve assembly **638** is illustrated. Base valve assembly **638** comprises piston **210**, rebound valve assembly **212**, compression valve assembly **214** and pressure sensitive valve assembly **616**. Piston **210** is attached to pressure tube **30** and separates lower working chamber **46** from reservoir chamber **52**. Piston **210** defines a central passage **224** extending between lower working chamber **46** and reservoir chamber **52**, the plurality of rebound fluid passages **226** extending between lower working chamber **46** and reservoir chamber **52** and the plurality of compression fluid passages **228** extending between lower working chamber **46** and reservoir chamber **52**.

Rebound valve assembly **212** comprises the one or more valve discs **230**, valve spring **232** and nut **234**. Valve discs **230** close the plurality of rebound fluid passages **226** and valve spring **232** is disposed between nut **234** and valve disc **230** to bias valve disc **230** against piston **210**. Fluid access to compression fluid passages **228** is provided by a plurality of apertures which extend through valve disc **230**. During a rebound stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from reservoir chamber **52** to lower working chamber **46**. The rebound stroke reduces the fluid pressure within lower working chamber **46** and the fluid pressure within reservoir chamber **52** will exceed the fluid pressure within lower working chamber **46**. The fluid pressure within reservoir chamber **52** will react against valve disc **230** and when the load on valve disc **230** from the fluid pressure exceeds the biasing load of valve spring **232**, valve disc **230** will unseat from piston **210** and fluid will flow from reservoir chamber **52** through rebound fluid passages **226** and into lower working chamber **46**. Valve spring **232** is designed to exert a minimum load against valve disc **230** such that rebound valve assembly **212** acts like a check valve during a rebound stroke and does not substantially contribute to the damping loads for shock absorber **20**. The damping load during a rebound stroke for shock absorber **20** is created by rebound valve assembly **64** of piston assembly **32**.

Compression valve assembly **214** comprises the one or more valve discs **240** and bolt **242**. Valve discs **240** close the plurality of compression fluid passages **228** and bolt **242** threadingly engages nut **234** to secure valve disc **240** against piston **210**. During a compression stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from lower working chamber **46** to reservoir chamber **52**. During the compression stroke, fluid pressure in lower working chamber **46** increases and this fluid pressure reacts against valve discs **240**. As the fluid pressure within lower working chamber **46** increases, the fluid pressure reacts against valve discs **240** and eventually valve discs **240** will deflect to open compression fluid passages **228**. Fluid will flow from lower working chamber **46**, through fluid passages **228** and into reservoir chamber **52**. The damping load during a compression stroke is created by compression valve assembly **214**. As described above, compression valve assembly **62** of piston assembly **32** acts like a check valve and does not substantially contribute to the damping loads for shock absorber **20**. Com-

pression valve assembly **214** is a normally closed compression valve assembly which is opened by the pressure differential between lower working chamber **46** and reservoir chamber **52**. The flow through compression valve assembly **214** is directly proportional to the pressure differential. The greater the pressure differential, the greater deflection of valve discs **140** and the greater the flow through compression valve assembly **214**.

Pressure sensitive valve assembly **616** comprises a pressure tube cylinder end **650**, a valve tube **652**, a cylinder end **654**, a piston and sleeve assembly **656** and a biasing spring **658** which is illustrated as a Belleville spring. Pressure tube cylinder end **650** is attached to pressure tube **30** and to valve tube **652**. Cylinder end **654** is attached to valve tube **652** and engages end cap **54**. Piston **210** is attached to piston and sleeve assembly **656** and piston and sleeve assembly **656** is slidably disposed within valve tube **652**. A spacer **660** is disposed between piston and sleeve assembly **656** and biasing spring **658**. A seal **662** seals the interface between piston and sleeve assembly **656** and valve tube **652**. Biasing spring **658** urges piston and sleeve assembly **656** towards pressure tube cylinder end **650**. Cylinder end **654** defines one or more apertures **664** which allow fluid flow between lower working chamber **46** and reservoir chamber **52**.

During a compression stroke, fluid pressure within lower working chamber **46** acts against the upper side of piston **210**. The fluid pressure within reservoir chamber **52** acts against the lower side of piston **210**. The biasing load of biasing spring **658** allows for the normal flow of fluid through compression valve assembly **214** as described above as long as the pressure differential across piston **210** does not generate sufficient load to overcome the biasing load of biasing spring **658**. Once the pressure differential across piston **210** generates sufficient load to overcome the biasing load of biasing spring **658**, piston **210** will cause piston and sleeve assembly **656** to slide down in valve tube **652**. As piston and sleeve assembly **656** approaches cylinder end **654**, biasing spring **658** will interface with cylinder end **654** to close or prohibit fluid flow from lower working chamber **46** to reservoir chamber **52** through apertures **664**. When the fluid pressure difference across piston **210** reduces, biasing spring **658** will again bias piston and sleeve assembly **656** against pressure tube cylinder end **650**. As illustrated, biasing spring **658** interfaces with cylinder end **654** but the present disclosure is not limited to this concept as other components could prohibit the fluid flow. Pressure sensitive valve assembly **616** is a normally open compression valve assembly which is closed by the pressure differential between lower working chamber **46** and reservoir chamber **52** where the pressure differential is determined by the velocity of piston assembly **32**.

The fluid pressure in lower working chamber **46** exponentially increases and the only flow between lower working chamber **46** and reservoir chamber **52** is through a bypass **666** defined by compression valve assembly **214** and cylinder end **654** or by compression valve assembly **214** and pressure sensitive valve assembly **616**. Bypass **666** can include a passage around or through cylinder end **654**. The area of bypass **666** and the instantaneous velocity of piston assembly **32** will define the final damping forces achieved. The increase in fluid pressure within lower working chamber **46** is a function of the velocity of piston assembly **32** and thus pressure sensitive valve assembly **616** is a pressure sensitive valve which opens and closes based upon the velocity of piston assembly **32**.

Referring now to FIG. **11**, a monotube shock absorber **720** is illustrated. Shock absorber **720** comprises a pressure tube **730**, a piston assembly **732**, a piston rod **734**, an accumulator piston **736** and a pressure sensitive valve assembly **738**.

Pressure tube **730** defines a working chamber **742**. Piston assembly **732** is slidably disposed within pressure tube **730** and divides pressure tube **730** into an upper working chamber **744** and a lower working chamber **746**. A seal is disposed between piston assembly **732** and pressure tube **730** to permit sliding movement of piston assembly **732** with respect to pressure tube **730** without generating undue frictional forces as well as sealing upper working chamber **744** from lower working chamber **746**. Piston rod **734** is attached to piston assembly **732** and extends through upper working chamber **744** and through an upper end cap or rod guide **750** which closes the upper end of pressure tube **730**. A sealing system seals the interface between rod guide **750**, pressure tube **730** and piston rod **734**. The end of piston rod **734** opposite to piston assembly **732** is adapted to be secured to the sprung or unsprung portion of vehicle **10**. The end of pressure tube **730** opposite to rod guide **750** is adapted to be connected to the other sprung or unsprung portion of vehicle **10**.

An rebound valve assembly **760** controls the movement of fluid between upper working chamber **744** and lower working chamber **746** to generate the damping forces during an extension movement of piston assembly **732** in pressure tube **730** as is well known in the art. A compression valve assembly **762** controls the movement of fluid between lower working chamber **746** and upper working chamber **744** to generate the damping forces during a compression movement of piston assembly **732** in pressure tube **730** as is well known in the art. Accumulator piston **736** separates lower working chamber **746** from an accumulator chamber **764** typically filled with a gas. Accumulator piston **736** is slidably disposed within pressure tube **730** and with accumulator chamber **764**, accumulator piston **736** compensates for the "rod volume" concept as is well known in the art.

Pressure sensitive valve assembly **738** is a pressure actuated valve assembly which comprises a cylinder end **766**, stem **150**, spool **152**, spool cap **154**, valve spring **156** and a bolt **768**. The cylinder end **766** may be fixedly secured to the pressure tube **730**. Stem **150** is disposed within a central passage **770** extending through cylinder end **766**. Stem **150** is secured to cylinder end **766** by bolt **768**. Bolt **768** defines a central fluid passage **772** which is in communication with fluid passage **160** in stem **150** to provide a bypass flow of fluid as described below.

Spool **152** is slidingly received over stem **150**. Upward movement of spool **152** on stem **150** is limited by flange **162** on stem **150** which engages shoulder **164** defined by spool **152**. Valve spring **156** biases shoulder **164** of spool **152** against flange **162** of stem **150** to allow fluid to flow from lower working chamber **46** into a plurality of fluid passages **776** extending through cylinder end **766**. Spool cap **154** is secured to spool **152**. Spool **152** defines the one or more holes **166**.

During a compression stroke, fluid pressure within lower working chamber **46** acts against spool **152** and spool cap **154** of pressure sensitive valve assembly **738**. The fluid pressure below cylinder end **766** acts against spool **152** and spool cap **154** of pressure sensitive valve assembly **738**. The fluid pressure is channeled to spool **152** and spool cap **154** through bypass passage **778**. The biasing of valve spring **156** allows for the normal flow of fluid through the plurality of fluid passages **776** to allow for the normal damping of shock absorber **720** since the fluid flows easily to the area between pressure sensitive valve assembly **738** and accumulator piston **736**. Once the pressure differential acting on spool **152** exceeds the biasing load of valve spring **156**, spool **152** will slide downward on stem **150** and close or prohibit fluid flow from lower working chamber **46** through the plurality of

passages **776**. Once the fluid pressure across spool **152** reduces, valve spring **156** will again bias spool **152** upward against flange **162**. When spool **152** closes or prohibits fluid flow, the fluid pressure in lower working chamber **46** exponentially increases and the only flow between lower working chamber **46** and the area below cylinder end **766** is through the one or more holes **166**. The area of the one or more holes **166** and the instantaneous velocity of piston assembly **732** will define the final damping forces achieved. The increase in fluid pressure within lower working chamber **746** is a function of the velocity of piston assembly **732** and thus pressure sensitive valve assembly **738** is a pressure sensitive valve which opens and closes based upon the velocity of piston assembly **732**. Pressure sensitive valve assembly **738** is a normally open compression valve assembly which is closed by the pressure differential between lower working chamber **746** and the area below cylinder end **766** where the pressure differential is determined by the velocity of piston assembly **732**.

Referring now to FIGS. **12** and **13**, base valve assembly **838** is illustrated. Base valve assembly **838** comprises cylinder end **110**, rebound valve assembly **112**, compression valve assembly **114** and a pressure sensitive valve assembly **816**. Cylinder end **110** is attached to pressure tube **30** and separates lower working chamber **46** from reservoir chamber **52**. Cylinder end **110** engages end cap **54** and it defines a plurality of fluid passages **122** open to reservoir chamber **52**. Cylinder end **110** defines the central passage **124** extending between lower working chamber **46** and reservoir chamber **52** through fluid passages **122**, the plurality of rebound fluid passages **126** extending between lower working chamber **46** and reservoir chamber **52** through fluid passages **122** and the plurality of compression fluid passages **128** extending between lower working chamber **46** and reservoir chamber **52** through fluid passages **122**.

Rebound valve assembly **112** comprises one or more valve discs **130** and valve spring **132**. Valve discs **130** close the plurality of rebound fluid passages **126** and valve spring **132** is disposed between pressure sensitive valve assembly **816** and valve disc **130** to bias valve disc **130** against cylinder end **110**. During a rebound stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from reservoir chamber **52** to lower working chamber **46**. The rebound stroke reduces the fluid pressure within lower working chamber **46** and the fluid pressure within reservoir chamber **52** will exceed the fluid pressure within lower working chamber **46**. The fluid pressure within reservoir chamber **52** will react against valve disc **130** and when the load on valve disc **130** from the fluid pressure exceeds the biasing load of valve spring **132**, valve disc **130** will unseat from cylinder end **110** and fluid will flow from reservoir chamber **52** through fluid passages **122**, through rebound fluid passages **126** and into lower working chamber **46**. Valve spring **132** is designed to exert a minimum load against valve disc **130** such that rebound valve assembly **112** acts like a check valve during a rebound stroke and does not substantially contribute to the damping loads for shock absorber **20**. The damping load during a rebound stroke for shock absorber **20** is created by rebound valve assembly **64** of piston assembly **32**.

Compression valve assembly **114** comprises one or more valve discs **140** and a bolt **142**. Valve discs **140** close the plurality of compression fluid passages **128** and bolt **142** threadingly engages pressure sensitive valve assembly **116** to secure valve disc **140** against cylinder end **110**. During a compression stroke of shock absorber **20**, the "rod volume" concept requires fluid to flow from lower working chamber **46** to reservoir chamber **52**. During the compression stroke, fluid pressure in lower working chamber **46** increases and this fluid pressure reacts against valve discs **140**. As the fluid pressure within lower working chamber **46** increases, the fluid pressure reacts against valve discs **140** and eventually valve discs **140** will deflect to open compression fluid passages **128**. Fluid will flow from lower working chamber **46**, through compression fluid passages **128**, through fluid passages **122** and into reservoir chamber **52**. The damping load during a compression stroke is created by compression valve assembly **114**. As described above, compression valve assembly **62** of piston assembly **32** acts like a check valve and does not substantially contribute to the damping loads for shock absorber **20**. Compression valve assembly **114** is a normally closed compression valve assembly which is opened by the pressure differential between lower working chamber **46** and reservoir chamber **52**. The flow through compression valve assembly **114** is directly proportional to the pressure differential. The greater the pressure differential, the greater deflection of valve discs **140** and the greater the flow through compression valve assembly **114**.

Pressure sensitive valve assembly **816** is a pressure actuated valve assembly which comprises cylinder end **110**, stem **150**, spool **152**, spool cap **154**, a valve spring **856** and a valve disc **858**. Valve spring **856** and valve disc **858** define a secondary valve assembly **860**. Stem **150** is disposed within central passage **124** and is secured to cylinder end **110** by bolt **142** of compression valve assembly **114**. Bolt **142** defines central fluid passage **158** and stem **150** defines central fluid passage **160** to provide for a pressure drop as described below.

Spool **152** is slidingly received over stem **150**. Upward movement of spool **152** on stem **150** is limited by flange **162** on stem **150** which engages shoulder **164** defined by spool **152**. Valve spring **132** of rebound valve assembly **112** and valve spring **856** of pressure sensitive valve assembly **116** biases shoulder **164** of spool **152** against flange **162** of stem **150** to allow fluid to flow from lower working chamber **46** into the plurality of compression fluid passages **128**. Spool cap **154** is secured to spool **152**. Spool **152** defines one or more holes **166**. Valve disc **858** is biased against spool **152** to close the one or more holes **166**.

During a compression stroke, fluid pressure within lower working chamber **46** acts against spool **152** and spool cap **154** of pressure sensitive valve assembly **816**. The fluid pressure within reservoir chamber **52** acts against spool **152** and spool cap **154** of pressure sensitive valve assembly **816**. The reservoir fluid pressure is channeled to spool **152** and spool cap **154** through fluid passages **122**, **158** and **160**. The biasing of valve spring **132** and valve spring **856** allows for the normal flow of fluid through compression valve assembly **114** as described above as long as the pressure difference across spool **152** does not generate sufficient load to overcome the biasing load of valve spring **132** and valve spring **856**. Once the pressure differential between fluid in lower working chamber **46** and reserve chamber **52** acting against surfaces on spool **152** and spool cap **154** exceeds the biasing load of valve spring **132** and valve spring **856**, spool **152** will slide downward on stem **150** and close or prohibit fluid flow from lower working chamber **46** to the plurality of compression fluid passages **128** as illustrated in FIG. **13**. Once the fluid pressure across spool **152** reduces, valve spring **132** and valve spring **856** will again bias spool **152** upward against flange **162**. When spool **152** closes or prohibits fluid flow, the fluid pressure in lower working chamber **46** exponentially increases and the only flow between lower working chamber **46** and reservoir chamber **58** is through the one or more holes **166** and compression valve assembly **114**. As discussed above, the one or more holes **166** are closed by valve disc **858**

which is biased against spool **152** by valve spring **856**. When spool **152** closes, before fluid flow can flow through the one or more holes **166**, the fluid pressure in lower working chamber **46** must overcome the biasing of valve spring **856**. The size of the one or more holes **166** will determine the pressure area open to valve disc **858** setting the opening point for valve disc **858**. If necessary, an additional port (not shown) can be added on the circumference of spool **152** for force characteristic tuning. The combined/total area of the one or more holes **166** plus any additional ports and the instantaneous velocity of piston assembly **32** will define the final damping forces achieved. The increase in fluid pressure within lower working chamber **46** is a function of the velocity of piston assembly **32** and thus pressure sensitive valve assembly **816** is a pressure sensitive valve which opens and closes based upon the velocity of piston assembly **32**. Pressure sensitive valve assembly **816** is a normally open compression valve assembly which is closed by the pressure differential between lower working chamber **46** and reservoir chamber **52** where the pressure differential is determined by the velocity of piston assembly **32**.

The movement of spool **152** can be controlled or damped by controlling the diameter of central fluid passage **158** of bolt **142**. As illustrated in FIG. **12**, fluid chamber **170** is located above bolt **142**. This volume must be displaced through central fluid passage **158** in order for spool **152** to move downward. By controlling the diameter of central fluid passage **158** the period of time that it takes spool **152** to move downward can be controlled. Thus, a damping effect can be achieved in regard to this motion of spool **152**.

Pressure sensitive valve assembly **816** can also be converted to an acceleration sensitive valve assembly. By eliminating central fluid passage **158** and eliminating spool cap **154**, pressure sensitive valve assembly **816** would be converted from a pressure sensitive valve assembly to an acceleration sensitive valve assembly. In this configuration, motion of spool **152** would be defined by the mass of spool **152** and the design for valve spring **132** and valve spring **856**. These specifications can be tuned to a specific desired frequency and will provide a similar increase in damping force once closed. Final damping force will be defined by providing bypass passage **166** as previously discussed.

The foregoing description of the embodiments has been provided for purposes of illustration and description. It is not intended to be exhaustive or to limit the invention. Individual elements or features of a particular embodiment are generally not limited to that particular embodiment, but, where applicable, are interchangeable and can be used in a selected embodiment, even if not specifically shown or described. The same may also be varied in many ways. Such variations are not to be regarded as a departure from the invention, and all such modifications are intended to be included within the scope of the invention.

What is claimed is:

**1**. A shock absorber comprising:

a pressure tube forming a working chamber;

a piston body slidably disposed within said working chamber, said piston body dividing said working chamber into an upper working chamber and a lower working chamber;

means for defining a fluid chamber in communication with one of said upper working chamber and said lower working chamber;

a compression valve assembly controlling fluid flow from said lower working chamber to said fluid chamber;

a pressure sensitive valve assembly separate from said compression valve assembly disposed between said lower working chamber and said fluid chamber, said pressure sensitive valve assembly movable from an open position allowing fluid flow to said compression valve assembly from said lower working chamber to a closed position restricting but not eliminating said fluid flow to said compression valve assembly from said lower working chamber based upon a velocity of said piston body sliding in said pressure tube; and

a secondary valve assembly separate from said pressure sensitive valve assembly and said compression valve assembly prohibiting all of said fluid flow to said compression valve assembly from said lower working chamber when said pressure sensitive valve assembly is in said closed position and when said secondary valve assembly is in a closed position.

**2**. The shock absorber according to claim **1**, wherein said defining means comprises a reserve tube surrounding said pressure tube to form said fluid chamber between said reserve tube and said pressure tube.

**3**. The shock absorber according to claim **1**, wherein said defining means comprises a piston assembly slidably disposed in said pressure tube, said fluid chamber being defined by said pressure tube.

**4**. The shock absorber according to claim **1**, wherein said pressure sensitive valve assembly comprises a cylinder end attached to said pressure tube, a spool movable between an open position and a closed position and a first biasing member urging said spool into said open position.

**5**. The shock absorber according to claim **4**, wherein said secondary valve assembly includes a valve disc and a second biasing member urging said valve disc against said spool.

**6**. The shock absorber according to claim **5**, wherein the second biasing member urges said spool into said open position.

**7**. The shock absorber according to claim **6**, wherein the spool defines one or more holes, the valve disc being urged against said spool to close said one or more holes.

**8**. The shock absorber according to claim **5**, wherein the spool defines one or more holes, the valve disc being urged against said spool to close said one or more holes.

**9**. The shock absorber according to claim **1**, wherein an increase of pressure of working fluid in said lower working chamber moves said pressure sensitive valve assembly from said open position to said closed position.

**10**. The shock absorber according to claim **1**, wherein said pressure sensitive valve assembly defines a first surface in direct contact with working fluid in said lower working chamber and a second surface in direct contact with working fluid in said fluid chamber.

**11**. The shock absorber according to claim **1**, wherein a difference in fluid pressure acting on said first and second surfaces moves said pressure sensitive valve assembly between said open and closed positions.

**12**. A shock absorber comprising:

a pressure tube forming a first fluid chamber;

a working fluid disposed within said first fluid chamber;

a piston body slidably disposed within said first fluid chamber, said piston body dividing said first fluid chamber into an upper working chamber and a lower working chamber;

a second fluid chamber in communication with said lower working chamber;

a first fluid valve assembly disposed between said lower working chamber and said second fluid chamber, said first fluid valve assembly allowing direct fluid flow from said second fluid chamber to said lower working cham-

ber while prohibiting fluid flow from said lower working chamber directly to said second fluid chamber;

a second fluid valve assembly disposed between said lower working chamber and said second fluid chamber, said second fluid valve assembly prohibiting fluid flow from said second fluid chamber to said lower working chamber while allowing fluid flow from said lower working chamber to said second fluid chamber;

a pressure sensitive valve assembly including a movable member spaced from the first and second fluid valve assemblies, said movable member of said pressure sensitive valve assembly including at least one hole extending therethrough, and said pressure sensitive valve assembly being disposed between said lower working chamber and said second fluid chamber, and wherein:

said pressure sensitive valve assembly operates independently from a position of said piston body within said first fluid chamber;

a first surface on said movable member of said pressure sensitive valve assembly always being in direct fluid contact with working fluid disposed within said second fluid chamber such that fluid pressure in said second fluid chamber acts directly on said first surface of said pressure sensitive valve assembly;

a second surface of said movable member of said pressure sensitive valve assembly being in direct fluid contact with working fluid disposed within said lower working chamber;

movement of said movable member of said pressure sensitive valve assembly causing said pressure sensitive valve assembly to change from an open position to a closed position, said pressure sensitive valve assembly then restricting fluid flow through said second fluid valve assembly when said pressure sensitive valve assembly is in said closed position such that fluid flow from said lower working chamber to said second fluid chamber is limited by an area of said hole in said movable member;

said pressure sensitive valve assembly being operable to move between said open and closed positions to control fluid flow through said second fluid valve assembly based upon a pressure differential between pressure of said working fluid in said second fluid chamber reacting against said second surface of said movable member and pressure of said working fluid in said lower working chamber reacting against said first surface of said movable member; the shock absorber further comprising:

a secondary valve assembly controlling fluid flow through said pressure sensitive valve assembly when said pressure sensitive valve assembly is in said closed position.

**13**. The shock absorber according to claim **12**, wherein said second fluid chamber comprises a reserve tube surrounding said pressure tube.

**14**. The shock absorber according to claim **12**, wherein said second fluid chamber is defined by said pressure tube, and wherein a piston assembly is slidably disposed in said pressure tube.

**15**. The shock absorber according to claim **12**, wherein said pressure sensitive valve assembly comprises a cylinder end attached to said pressure tube, a spool slidably disposed on said cylinder end, said spool movable between an open position and a closed position and a biasing member urging said spool into said open position, said pressure of said working fluid in said one of said upper working chamber and said lower working chamber urging said spool into said closed position.

**16**. The shock absorber according to claim **12**, wherein said pressure sensitive valve assembly is fixedly secured to said pressure tube.

**17**. The shock absorber according to claim **12**, wherein said pressure sensitive valve assembly defines a fluid passage extending through said first and second fluid valve assemblies.

**18**. The shock absorber according to claim **12**, wherein said pressure sensitive valve assembly comprises a stem, a spool, a spool cap and a spring, said spool cap being said movable member.

**19**. The shock absorber according to claim **12**, wherein said movable member is not a component of the first fluid valve assembly.

**20**. A shock absorber comprising:

a pressure tube forming a first fluid chamber;

a working fluid disposed within said first fluid chamber;

a piston body slidably disposed within said first fluid chamber, said piston body dividing said first fluid chamber into an upper working chamber and a lower working chamber;

means for defining a second fluid chamber in communication with said lower working chamber;

a first fluid valve assembly disposed between said lower working chamber and said second fluid chamber, said first fluid valve assembly allowing direct fluid flow from said second fluid chamber to said lower working chamber while prohibiting fluid flow from said lower working chamber directly to said second fluid chamber;

a second fluid valve assembly disposed between said lower working chamber and said second fluid chamber, said second fluid valve assembly prohibiting fluid flow from said second fluid chamber to said lower working chamber while allowing fluid flow from said lower working chamber to said second fluid chamber;

a pressure sensitive valve assembly different from the first and second fluid valve assemblies disposed between said lower working chamber and said second fluid chamber, said pressure sensitive valve assembly including a movable member having a hole forming a fluid passage therethrough; wherein

said pressure sensitive valve operates independently from a position of said piston body within said first fluid chamber;

a first surface of said pressure sensitive valve assembly always being in direct contact with working fluid disposed within said second fluid chamber;

a second surface of said pressure sensitive valve assembly being in direct contact with working fluid disposed within said lower working chamber;

said pressure sensitive valve assembly is movable from an open position to a closed position based only upon a pressure differential between pressure of said working fluid in said second fluid chamber and pressure of said working fluid in said lower working chamber, said pressure sensitive valve assembly using said hole to limit fluid flow through said second fluid valve assembly when said pressure sensitive valve assembly is in said closed position; the shock absorber further comprising:

a secondary valve assembly controlling fluid flow through said pressure sensitive valve assembly when said pressure sensitive valve assembly is in said closed position.

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